Rules and Regulations for the Classification of Inland Waterways Ships

July 2022

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Inland Waterways Ships

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Rules updating

The Rules are published periodically and changed through a system of Notices between releases.

July 2022

■ *Section 1*
Background

1.1 Lloyd’s Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd’s Register Group Limited, including but not limited to: Lloyd’s Register EMEA, Lloyd’s Register Asia, Lloyd’s Register North America, Inc., and Lloyd’s Register Central and South America Limited. Lloyd’s Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as ‘LR’.

■ *Section 2*
Governance

2.1 Lloyd’s Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;

appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:	Areas:
Australia (via Lloyd's Register Asia)	Benelux (via Lloyd's Register EMEA)
Canada (via Lloyd's Register North America, Inc.)	Central America (via Lloyd's Register Central and South America Ltd)
China (via Lloyd's Register Asia)	Nordic Countries (via Lloyd's Register EMEA)
Egypt (via Lloyd's Register EMEA)	South Asia (via Lloyd's Register Asia)
Federal Republic of Germany (via Lloyd's Register EMEA)	Asian Shipowners (via Lloyd's Register Asia)
France (via Lloyd's Register EMEA)	Greece (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)	

Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

■ *Section 3* **Technical Committee**

3.1 LR maintains a Technical Committee, at present comprised of a maximum of 80 members, and additionally an Offshore Technical Committee with specific responsibility for LR’s Rules for Offshore Units, at present comprised of a maximum of 80 members. Membership of the Technical Committees includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd’s Register Group Limited
- Chairman of the Classification Committee of Lloyd’s Register Group Limited

Members Nominated by:

- Technical Committee or Offshore Technical Committee
- Professional bodies representing technical disciplines relevant to the industry
- National and International trade associations with competence relevant to technical issues related to LR's business

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committees.
(b) A maximum of five further representatives from National Administrations may be co-opted to serve on the Technical Committees. Representatives from National Administrations may also be elected as members of the Technical Committees as Nominated Members.
(c) Further persons may be co-opted to serve on the Technical Committees by the relevant Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committees is to consider:

(a) any technical issues connected with LR’s business;
(b) any proposed alterations in the existing Rules;
(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions and Codes, or Common Rules, Unified Requirements and Interpretations adopted by the International Association of Classification Societies, these may be implemented by LR without consideration by the relevant Technical Committee, although any such changes may be provided to the Technical Committees for information.

Where changes to the Rules are required by LR to enable existing technical requirements within the Rules to be recognised as Class Notations or Descriptive Notes, these may be implemented by LR without consideration by the relevant Technical Committee, although any such changes will be provided to the relevant Technical Committee for information

3.5 The term of office of the Chairman and of all members of each Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the relevant Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committees are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Matters may also be considered by the Technical Committees by correspondence.

3.8 Any proposal involving any alteration in, or addition to the General Regulations, of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than the General Regulations, will following consideration and approval by the relevant Technical Committee either at a meeting of that Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committees are empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*
Naval Ship Technical Committee

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd's Register Group Limited

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules. Where appropriate, Naval Ship Technical Committee may also recognise alternative LR Rule requirements that have been approved by the other Lloyd's Register Technical Committee as adjunct to the Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, the General Regulations of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than the General Regulations, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

Section 5
Applicability of Classification Rules and Disclosure of Information

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval. Recognising the long time period that may occur between the initial design contract and the contract for construction for offshore units for fixed locations, the date determining effective classification requirements will be specially considered by LR in such cases.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System. LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*
Ethics

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*
Non-Payment of Fees

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*
Limits of Liability

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as ‘Lloyd's Register’. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

8.4 Except in the circumstances of section *Pt 1, Ch 1, 8 Limits of Liability 8.2* above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

■ *Section 1*
Conditions for classification

1.1 General

1.1.1 These Rules and Regulations are framed for Inland Waterways Ships operating in Zone 3. Proposed scantlings and arrangements for ships intended to operate in Zones 2 or 1, will be specially considered. *See also Pt 1, Ch 2, 2.1 Definitions 2.1.2* for Zone definitions.

1.1.2 Ships referred to in this Chapter are defined in *Pt 3 Ship Structures (General)* and *Pt 4 Ship Structures (Ship Types)* of these Rules.

Machinery referred to in this Chapter is defined in *Pt 5 Main and Auxiliary Machinery* and *Pt 6 Control, Electrical and Fire* of these Rules.

1.1.3 Ships built in accordance with Lloyd's Register's (hereinafter referred to as LR) Rules and Regulations, or in accordance with requirements equivalent thereto, will be assigned a class in the *Register Book* and will continue to be classed as long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery and with the certification requirements of *Pt 1, Ch 2, 1.1 General*.

1.1.4 The Classification Committee, in addition to requiring compliance with LR's Rules, may require to be satisfied that ships of special types are suitable for the conditions of the service contemplated.

1.1.5 Any damage, defect or breakdown, grounding, serious deficiency, detention or arrest which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay. Any detention or arrest is also to be reported to LR without delay.

1.1.6 The Rules are framed on the understanding that ships will be properly loaded and handled. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading. The Classification Committee may require additional strengthening to be fitted in any ship, which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design, or where it is desired to make provision for exceptional loaded or ballast conditions. In such cases, particulars are to be submitted for consideration, *see also* the relevant ship type Chapters in *Pt 4 Ship Structures (Ship Types)*.

1.1.7 The Rules are framed on the understanding that ships will not be operated in environmental conditions more severe than those agreed for the design basis and approval, without the prior agreement of LR.

1.1.8 For ships, the arrangements and equipment of which are required to comply with the requirements of either the:

- European Agreement concerning the international carriage of dangerous goods by inland waterways (ADN); or
- European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN); or
- Any National regulations specified by the Government of the Flag State,

and applicable Amendments thereto, the Classification Committee requires the applicable Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised.

1.2 Advisory services

1.2.1 The Rules do not cover certain technical characteristics, such as stability, trim, hull vibration, etc. but advice may be given on such matters without any assumption of responsibility for such advice.

■ *Section 2* Character of classification and class notations

2.1 Definitions

Note For the purpose of class notations, the definitions given in *Pt 1, Ch 2, 2.1 Definitions 2.1.2* will apply.

2.1.2 **Zone 1.** A zone where the maximum significant wave height based on long-term significant wave height statistics, excluding the highest five per cent of the observed waves, does not exceed 1,6 m.

2.1.3 **Zone 2.** A zone where the maximum significant wave height based on long-term significant wave height statistics, excluding the highest five per cent of the observed waves, does not exceed 1,0 m.

2.1.4 **Zone 3.** A zone where the maximum significant wave height based on long-term significant wave height statistics, excluding the highest five per cent of the observed waves, does not exceed 0,5 m.

2.1.5 **Type notation.** One of the following Notations will be assigned to ships indicating that the ship has been arranged and constructed in compliance with the Rules and as defined in the relevant Chapter of *Pt 4 Ship Structures (Ship Types)*. Details regarding further extensions of Class Notations as applicable for specific ship types are given in these Chapters as well.

- **A1 I.W.W. Cargo Ship** or **A1 I.W.W. Cargo Barge**. *See Pt 4, Ch 1 Dry Cargo Ships*
- **A1 I.W.W. Container Ship** or **A1 I.W.W. Container Barge**. *See Pt 4, Ch 1 Dry Cargo Ships*
- **A1 I.W.W. Bulk Carrier** or **A1 I.W.W. Bulk Carrier Barge**. *See Pt 4, Ch 1 Dry Cargo Ships*
- **‘A1 I.W.W. Ferry’**, **‘A1 I.W.W. Roll on-Roll off Ship’** or **‘A1 I.W.W. Roll on-Roll off Barge’**. *See Pt 4, Ch 2 Ferries and Roll on-Roll off Ships*
- **‘A1 I.W.W. Pontoon’** or **‘A1 I.W.W. Pontoon, self propelled’**. *See Pt 4, Ch 3 Pontoons*
- **‘A1 I.W.W. Tanker Type G’** or **‘A1 I.W.W. Barge Type G’**. *See Pt 4, Ch 5 Tankers of Type G*
- **‘A1 I.W.W. Tanker Type C’** or **‘A1 I.W.W. Barge Type C’**. *See Pt 4, Ch 6 Tankers of Types C and N*
- **‘A1 I.W.W. Tanker Type N Closed’** or **‘A1 I.W.W. Barge Type N Closed’**. *See Pt 4, Ch 6 Tankers of Types C and N*
- **‘A1 I.W.W. Tanker Type N Closed, Double Hull’** or **'A1 I.W.W. Barge Type N Closed, Double Hull’**. *See Pt 4, Ch 6 Tankers of Types C and N*
- **‘A1 I.W.W. Tanker Type N Open with flame screens’** or **‘A1 I.W.W. Barge Type N Open with flame screens’**. *See Pt 4, Ch 6 Tankers of Types C and N*
- **'A1 I.W.W. Tanker Type N Open with flame screens, Double Hull'** or **'A1 I.W.W. Barge Type N Open with flame screens, Double Hull'**. *See Pt 4, Ch 6 Tankers of Types C and N*
- **‘A1 I.W.W. Tanker Type N Open’** or **‘A1 I.W.W. Barge Type N Open’**. *See Pt 4, Ch 6 Tankers of Types C and N*
- **'A1 I.W.W. Tanker Type N Open, Double Hull'** or **'A1 I.W.W. Barge Type N Open, Double Hull'**. *See Pt 4, Ch 6 Tankers of Types C and N*
- **‘A1 I.W.W. – Water tanker’** or **‘A1 I.W.W. – Wine tanker’** or **‘A1 I.W.W. – Edible oil tanker’** or **‘A1 I.W.W. – Water barge’** or **‘A1 I.W.W. – Wine barge’** or **‘A1 I.W.W. – Edible oil barge’**. *See Pt 4, Ch 7 Water Tankers, Wine Tankers and Edible Oil Tankers*
- **‘A1 I.W.W. Pusher Tug’** or **‘A1 I.W.W. Launch’**. *See Pt 4, Ch 8 Tugs, Pusher Tugs and Launches*
- **‘A1 I.W.W. Passenger Ship’**. *See Pt 4, Ch 9 Passenger Ships*.

2.1.6 **Cargo notation.** A notation indicating that the ship has been designed, modified or arranged to carry one or more particular cargoes, e.g. sulphuric acid. Ships with one or more particular cargo notations are not thereby prevented from carrying other cargoes for which they are suitable.

2.1.7 **Loading sequence notation (L.S.).** A notation indicating that the ship has been designed, modified or arranged to be loaded and/or discharged according to a special or to a defined sequence, e.g. loading sequence ‘O’, loading sequence ‘D’, *see Pt 3, Ch 4, 2 General* and relevant ship type Chapters in *Pt 4 Ship Structures (Ship Types)*.

2.1.8 **Loading notation.** A notation indicating that the ship has been designed, modified or arranged for unusual and/or non-uniform cargo distributions, e.g. 'specified non-uniform loading conditions', *see Pt 3, Ch 4, 2 General* and relevant ship type Chapters in *Pt 4 Ship Structures (Ship Types)*.

2.1.9 **Ice notation.** A notation indicating that the ship has been designed, modified or arranged to navigate in ice:

ICE.

2.1.10 **Zone notation.** A notation indicating that the ship has been designed, modified or arranged to operate in Zones 1 and/or 2, where conditions as specified for the particular zone are not being exceeded during any voyage of the ship.

2.1.11 **Dangerous Goods notation.** Double-hull dry cargo ships built in compliance with Chapter 9, Section 9.1.0.80 of the ADN and complying with the additional requirements of *Pt 4, Ch 1, 12 Additional requirements for ships carrying dangerous goods* will be eligible to be classed:

DG.

2.1.12 **Pressure valve setting notation.** Tankers complying with the requirements of *Pt 4, Ch 5 Tankers of Type G*, *Pt 4, Ch 6 Tankers of Types C and N* or *Pt 4, Ch 7 Water Tankers, Wine Tankers and Edible Oil Tankers* will, in case of tanks of the closed type, have their design pressure valve setting of the relief valves of the cargo tanks entered in the class notation, e.g.:

p.v. +50 kPa.

2.1.13 **Specific gravity notation**. Tankers complying with the requirements of *Pt 4, Ch 5 Tankers of Type G*, *Pt 4, Ch 6 Tankers of Types C and N* or *Pt 4, Ch 7 Water Tankers, Wine Tankers and Edible Oil Tankers* will have the design specific gravity of the cargo tanks entered in the class notation, e.g.:

S.G. 1.20.

2.1.14 Corrosion resistant materials. Tankers complying with the requirements of *Pt 4, Ch 5 Tankers of Type G*, *Pt 4, Ch 6 Tankers of Types C and N* or *Pt 4, Ch 7 Water Tankers, Wine Tankers and Edible Oil Tankers* where the cargo tanks have been constructed of corrosion resistant materials, e.g. stainless steel, or have been lined with corrosion resistant linings, e.g. rubber lining, will have the following notations entered in the class notation:

'CR (s.stl)', 'CR (r.l)'.

2.2 Character symbols

2.2.1 All Inland Waterways Ships, when classed, will be assigned one or more character symbols as applicable. For the majority of ships, the character assigned will be ✠ **A1 I.W.W**. or **A1 I.W.W**.

2.2.2 A full list of character symbols for which ships may be eligible is as follows:

(a) ✠ This distinguishing mark will be assigned, at the time of classing, to new ships constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Classification Committee.

(b) **A** This character letter will be assigned to all ships which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

(c) **1** This character figure will be assigned to:

   (i) Ships having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.

   (ii) Ships classed for a special service, for which no specific anchoring and mooring Rules have been published, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Classification Committee as suitable and sufficient for the particular service.

   (iii) Ships having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with established National or International Regulations and approved by the Classification Committee as suitable and sufficient for the particular service. The service limits where applicable may be entered in the class notation.

(d) **N** This character letter will be assigned to ships on which the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

(e) **T** This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or pushed, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or pushing equipment which has been approved by the Classification Committee as suitable and sufficient for the intended service.

2.2.3 In cases where the equipment is found to be seriously deficient in quality or quantity, the class of the ship will be liable to be withheld.

2.3 Class notations (hull)

2.3.1 When considered necessary by the Classification Committee, or when requested by an Owner and agreed by the Classification Committee, a class notation will be appended to the character of classification assigned to the ship. This class notation will consist of one of, or a combination of: a type notation, a cargo notation, a loading sequence notation, a loading notation, an **ICE** notation and zone notation, e.g. **A1 I.W.W., L.S. 'O', ICE**, **Zone 2**.

2.3.2 Details of additional requirements in view of a ship type, particular cargoes, loading sequence, Ice or Zones 1 and 2, are given in the Chapters of *Pt 3 Ship Structures (General)* and *Pt 4 Ship Structures (Ship Types)* which apply to such ships and cargoes.

2.3.3 Service extension notations (service in areas which are not considered as Inland Waterways) may be assigned where, under specified conditions, the ship operates on an agreed route or in an agreed operating area. These conditions are such that the structural and system requirements specified in these Rules are sufficient.

These conditions are to be included in the class notation (e.g. geographical limits, maximum permissible distance out to sea, wind force, sea condition), as appropriate.

Where operation of the ship in the extended service area is permitted in association with defined loading conditions only, this service restriction is also to be included in the class notation.

These notations may be assigned in one of the following forms:

(a) **Specified route service.** Service between two or more ports or other geographical features, which will be indicated in the *Register Book*, e.g. 'Service between Flushing and Ostend, maximum five miles seaward and windforce not exceeding Beaufort scale 5 from sea or Beaufort scale 6 from land and in association with defined loading conditions'.
(b) **Specified operating area service.** Service within one or more geographical area(s), which will be indicated in the *Register Book*, e.g. 'Baltic Sea Service' (within specified geographical limits and under specified conditions).

2.4 Class notations (machinery)

2.4.1 The following class notations may be assigned as considered appropriate by the Classification Committee.

IGS = This notation will be assigned when a tanker, complying with the requirements of *Pt 4, Ch 5 Tankers of Type G*, *Pt 4, Ch 6 Tankers of Types C and N* or *Pt 4, Ch 7 Water Tankers, Wine Tankers and Edible Oil Tankers*, is fitted with approved arrangements for inerting the cargo tanks.

✠ **LMC** = This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations, *see also Pt 5, Ch 1, 7.1 General*.

$\overline{✠}$ **LMC** = This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognised authority in accordance with Rules and Regulations equivalent to those of LR and has been installed and tested under LR's Special Survey in accordance with LR's Rules and Regulations.

[✠] **LMC** = This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for essential services that are in compliance with LR Rules and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See Pt 1, Ch 2, 2.7 Application notes 2.7.2*.

LMC = This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey but the existing machinery, its installation and arrangement, has been tested and found to be acceptable to LR. This notation is assigned to existing ships in service accepted or transferring into LR class.

MCH = This notation will be assigned when the propelling and essential auxiliary machinery has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for essential services supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See Pt 1, Ch 2, 2.7 Application notes 2.7.3*.

2.4.2 Machinery class notations will not be assigned to ships of which the hulls are not classed or intended to be classed with LR.

2.4.3 The notations ✠ **LMC**, $\overline{\maltese}$ **LMC**, [✠] **LMC**, **LMC** (without ✠) and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

2.5 Class notations (Environmental Protection)

2.5.1 The following class notations are associated with the design and operation of a ship and may be assigned as considered appropriate by the Classification Committee, on application from the Owners:

ABN( ) This notation will be assigned where a vessel has had its airborne noise measured and certified in accordance with LR's *ShipRight Additional Design and Construction Procedure for the determination of airborne noise emissions from marine vessels*, and the sound power and sound pressure are found to be less than the assessment criterial limits it contains. The parentheses are to contain the characters associated with the most stringent assessment criteria limits that the airborne noise of the vessel satisfies.

2.6 Descriptive notes

2.6.1 In addition to any class notations, an appropriate descriptive note may be entered in Column 6 of the *Register Book* indicating the type of ship in greater detail than is contained in the class notation, and/or providing additional information about the ship's design and construction. This descriptive note is not a LR classification notation and is provided solely for information.

2.6.2 **ShipRight()**. Where one or more of LR's ShipRight procedures as detailed in the *Rules and Regulations for the Classification of Ships, July 2022*, *Pt 1, Ch 2, 2.8 Descriptive notes 2.8.2* have been satisfactorily applied, then a descriptive note showing the associated characters of the procedure(s) within brackets will, at all Owner's request, be entered in column 6 of the *Register Book*, preceded by the word **ShipRight**, e.g. **ShipRight(IHM, SERS)**.

2.7 Application notes

2.7.1 **Propelling and essential auxiliary machinery** includes machinery, equipment and systems installed for the ship to be under inland waterway navigation conditions and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the ship, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion and steering systems.
(e) The operation and functioning of emergency machinery and equipment.

2.7.2 **Manufacturer's certificate** for assignment of the [✠] **LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) The ship is a cargo ship or a tanker that is required to comply with specific Regulatory Body for Inland Maritime Transport requirements for construction under survey relating to the carriage of particular types of hazardous cargoes such as oils, chemicals and dangerous goods.
(b) The class notation is acceptable to the relevant Administration.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(e) The design and manufacture standards for all machinery and associated systems are the applicable LR Rules.
(f) The machinery and equipment is manufactured under a recognised quality control system.

(g) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

2.7.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:

(a) The ship is a cargo ship or a tanker that is not required to comply with specific Regulatory Body for Inland Maritime Transport requirements for construction under survey relating to the carriage of particular types of hazardous cargoes such as oils, chemicals and dangerous goods.
(b) Propulsion power is provided by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(c) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(d) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any engine is not greater than 300 mm.
(e) The design and manufacturing standards for machinery and associated engineering systems are the applicable LR Rules or other marine standards acceptable to LR.
(f) The machinery and equipment is manufactured under a recognised quality control system.

■ *Section 3* Surveys – General

3.1 Statutory surveys

3.1.1 The Classification Committee will act, when authorised on behalf of Governments, in respect of National and International statutory safety and other requirements for passenger, cargo and other ship types.

3.2 New construction surveys

3.2.1 When it is intended to build a ship for classification with LR, constructional plans and all necessary particulars relevant to the hull, equipment and machinery as detailed in the Rules, are to be submitted for approval before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

3.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Classification Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be assigned.

3.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to be tested in accordance with the requirements of LR’s *Rules for the Manufacture, Testing and Certification of Materials, July 2022*, (hereinafter referred to as the Rules for Materials). The steel is to be manufactured by an approved process at an approved works. Alternatively, tests will be required to demonstrate the suitability of the steel.

3.2.4 New ships intended for classification are to be built under LR’s Special Survey. From the commencement of the work until the completion of the ship, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.5 Copies of approved plans (showing the ship as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by the attending Surveyors, and may be required to be kept on board.

3.2.6 When the machinery is constructed under LR’s Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.7 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with LR’s Rules and Regulations.

3.2.8 The date of completion of the Special Survey during construction of ships built under LR's survey will normally be taken as the date of build to be entered in the Ship Records. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the Ship Records.

3.2.9 When a ship, upon completion, is not immediately commissioned but is laid up for a period, the Classification Committee, upon application by the Owner, prior to the ship proceeding to sea, will direct an examination to be made by the Surveyors which may include a survey in dry dock. If, as the result of such a survey, the hull and machinery are reported in all respects to be in accordance with applicable Rule requirements, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

3.3 Existing ships

3.3.1 **Classification of ships not built under survey.** The requirements of the Classification Committee for the classification of ships which have not been built under LR's Survey are indicated in *Pt 1, Ch 3 Periodical Survey Regulations*. Special consideration will be given to ships transferring class to LR from another recognised Classification Society.

3.3.2 **Reclassification.** When reclassification or class reinstatement is desired for a ship for which the class previously assigned by LR has been withdrawn or suspended, the Classification Committee will direct that a survey appropriate to the age of the ship and to the circumstances of the case, be carried out by the Surveyors. If, at such survey, the ship is found to be or is placed in a condition in accordance with the requirements of the Rules and Regulations, the Classification Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

3.3.3 The Classification Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the ship indicates this to be appropriate.

3.3.4 **Unscheduled surveys**. Where the Classification Committee has concern about the condition of a ship and/or the equipment an unscheduled survey may be required at any time to determine the actual condition.

3.4 Repairs and alterations

3.4.1 All repairs to hull, equipment and machinery which may be required in order that a ship may retain her class, *see Pt 1, Ch 2, 1.1 General 1.1.5*, are to be carried out to the satisfaction of the Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of the Surveyors at the earliest opportunity thereafter.

3.4.2 When at any survey the Surveyors consider repairs to be necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Classification Committee by the Surveyors.

3.4.3 When, at any survey, it is found that any damage, defect or breakdown (*see Pt 1, Ch 2, 1.1 General 1.1.5*) is of a nature that does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Classification Committee for consideration.

3.4.4 If a ship which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

3.4.5 If a ship which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

3.4.6 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval, and such alterations are to be carried out to the satisfaction of the Surveyors.

3.5 Existing ships – Periodical Surveys

3.5.1 All classed ships having a service extension notation and regularly operating in sea areas for which a National or International Load Line Certificate is issued, are to be subjected to Annual Surveys. These surveys become due at yearly intervals, the first survey one year from the date of build or from the date of the Special Survey for classification, and should be held concurrently with the periodical load line inspection. The survey may be commenced within the period of three months before the due date and is to be completed not later than three months after the due date. The date of the last Intermediate Survey will be recorded on the LR Class Direct website.

3.5.2 All classed passenger ships are to be subjected to Annual Surveys. These surveys become due at yearly intervals, the first survey one year from the date of build or from the date of the Special Survey for classification. The survey may be

commenced within the period of three months before the due date and is to be completed not later than three months after the due date. The date of the last Special Survey will be recorded on the LR Class Direct website.

3.5.3 All classed ships, other than as mentioned in *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.1* and *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.2*, are to be subjected to Intermediate Surveys. These surveys become due 30 months after the date of build or of the previous Special Survey and are to be completed within 6 months before and after the Intermediate Survey due date. The date of the last Intermediate Survey will be recorded on the LR Class Direct website.

3.5.4 All classed ships are to be subjected to Special Surveys. These surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for classification, and thereafter five years from the date of the previous Special Survey. The date of the last Special Survey will be recorded on the LR Class Direct website.

3.5.5 Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the ship is registered and/or of International Conventions if the ship is also intended to make international voyages.

3.5.6 It is the responsibility of Owners to ensure that all surveys for the maintenance of class are carried out at the proper time and in accordance with the Regulations.

3.5.7 For ships mentioned in *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.1*, the ship is to be dry-docked or placed on a slipway, between the second and third year after the date of build or the last Special Survey, for examination in accordance with *Pt 1, Ch 2, 3.2 New construction surveys 3.2.3* to be carried out concurrently with the periodical load line inspection, where practicable.

3.5.8 The Owners should also notify LR whenever a ship can be examined in dry dock or on a slipway on account of damage or defects sustained between Periodical Surveys.

3.5.9 When it is inconvenient for an Owner to fulfil all the requirements of a Special Survey at its due date, the Committee will be prepared to consider its extension, either wholly or in part, provided that LR's Surveyors are afforded an opportunity, prior to the due date, of assessing the general condition of the hull. For this purpose, the Classification Committee will normally call for a General Examination of the ship of sufficient extent and which may include dry-docking (depending on age and records of the ship) to be assured that its condition is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date. Attention is drawn to relevant regulations of the National Authorities of the country where the ship is registered. On completion of the Hull Special Survey, the assigned date will be the last date the ship was under survey. The date assigned is not to exceed six years from the previous due date.

3.5.10 Machinery is to be submitted to the surveys detailed in *Pt 1, Ch 3, 10 Machinery surveys – General requirements*.

3.5.11 Complete Surveys of machinery become due at five-yearly intervals, the first one five years from the date of build or date of first classification as recorded in Class Direct, and thereafter five years from the date of the previous Complete Survey.

3.5.12 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

3.5.13 Boiler Surveys are to be carried out as stated in *Pt 1, Ch 3, 13 Boilers*. The date of the last Boiler Survey will be recorded on the LR Class Direct website.

3.5.14 Steam pipes Surveys are to be carried out as stated in *Pt 1, Ch 3, 14 Steam pipes*. The date of the last Steam pipes Survey will be recorded on the LR Class Direct website.

3.5.15 Screwshaft Surveys are to be carried out as stated in *Pt 1, Ch 3, 15 Screwshafts, tube shafts and propellers*. The date(s) of the last Screwshaft Survey(s) will be recorded on the LR Class Direct website.

3.5.16 Where an inert gas system is fitted on board a ship, the system is to be surveyed at 2½-yearly intervals or at the Intermediate Survey and at the Special Survey. Survey requirements are given in *Pt 1, Ch 3, 16 Inert gas systems*.

3.5.17 When it is inconvenient for an Owner to fulfil all the requirements of a Complete Machinery Survey at its due date, the Committee will be prepared to consider an extension, either wholly or in part, provided that LR's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the machinery. For this purpose, the Classification Committee will normally call for a General Examination to be made, of sufficient extent to assure them that the condition of the machinery is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date. Attention is drawn to relevant Regulations of the National Authorities of the country where the ship is registered. On completion of the Machinery Survey, the assigned date will be the last date the ship was under survey. The date assigned is not to exceed six years from the previous due date.

3.5.18 Where the ship is fitted with classed dynamic positioning equipment, the system is to be examined at each Intermediate Survey and at the due time of the Complete Survey of machinery in accordance with the requirements of *Pt 1, Ch 3, 10.2 Intermediate Surveys 10.2.4* and *Pt 1, Ch 3, 10.3 Complete Survey of machinery 10.3.13*.

3.5.19 Where the Committee has agreed to an Owner's request to assign the notation 'laid up', the ship may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey /Intermediate Survey due date and in addition an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey/Intermediate Survey due date.

3.6 Certificates

3.6.1 When the required reports, on completion of the Special Survey of new or existing ships which have been submitted for classification, have been received from the Surveyors and classification has been agreed by the Classification Executive, a Certificate of Classification may be issued by an authorised Surveyor. After approval by the Classification Committee, a certificate of First Entry of Classification, signed by LR's Chairman or the Chairman of the Classification Committee, will be issued to the contracting Builders or Owners.

3.6.2 A Certificate of Class valid for five years subject to Annual and/or Intermediate Surveys will also be issued.

3.6.3 The Surveyors are permitted to issue provisional (interim) certificates to enable a ship intended for classification, or already classed, with LR to commence service or to proceed on its voyage (or to continue service in the case of a fixed or tethered ship) provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for classification or for continuance of class, but in all cases are subject to confirmation by the Classification Committee.

3.6.4 The full class notation and abbreviated descriptive notes shall be stated on the Certificate of Class.

3.7 Notice of surveys

3.7.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Classification Committee. Information is available to Owners on the Class Direct website.

3.7.2 LR will make available to an Owner timely notice about forthcoming surveys by means of a *Quarterly Listing of Surveys*, *Conditions of Class and Memoranda*. This can be requested from the LR Class Direct website. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the LR Class Direct website.

3.8 Withdrawal/Suspension of class

3.8.1 When the class of a ship, for which the Regulations as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Classification Committee in consequence of a request from the Owner, the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

3.8.2 When the Regulations as regards surveys on the hull, equipment or machinery have not been complied with and the ship is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation will be assigned.

3.8.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey has not been completed within the prescribed range of dates for the survey.

3.8.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.9*), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.

3.8.5 When, in accordance with *Pt 1, Ch 2, 3.4 Repairs and alterations 3.4.3* of the Regulations, a condition of class is imposed, this will be assigned a due date for completion and the ship's class will be subject to a suspension procedure if the condition of class is not dealt with, or postponed by agreement, by the due date.

3.8.6 When it is found, from the reported condition of the hull or equipment or machinery of a ship, that an Owner has failed to comply with *Pt 1, Ch 2, 1.1 General 1.1.5*, *Pt 1, Ch 2, 3.4 Repairs and alterations 3.4.1* or *Pt 1, Ch 2, 3.4 Repairs and alterations 3.4.5*, the class will be liable to be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently

serious, the suspension or withdrawal of class may be extended to include other ships controlled by the same Owner, at the discretion of the Classification Committee.

3.8.7 When it is found that a ship is being operated in a manner contrary to that agreed at the time of classification, or is being operated in environmental conditions which are more onerous or in areas other than those agreed by the Committee, the class will be liable to be automatically withdrawn or suspended.

3.8.8 Where a ship has been detained following an intervention by local authorities on two or more occasions in a two year period, with serious deficiencies found, then the class will be liable to be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation will be assigned. In these cases, a period of notice, not exceeding 3 months, may be given prior to any suspension or withdrawal of class.

3.8.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will be published by members of the LR Group. In cases where class has been suspended by the Classification Committee and it becomes apparent that the Owners are no longer interested in retaining LR’s class it will be withdrawn.

3.8.10 For reclassification and reinstatement of class, *see Pt 1, Ch 2, 3.3 Existing ships 3.3.2*.

3.9 Appeal from Surveyors’ recommendations

3.9.1 If the recommendations of the Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Classification Committee who may direct a Special Examination to be held.

3.10 Force majeure

3.10.1 If due to circumstances reasonably beyond the Owner's or LR's control, as defined below, the ship is not in a port when surveys become overdue the Classification Committee may allow the ship to sail, in class, directly to an agreed discharge port and then, if necessary, in ballast to an agreed repair facility at which the survey can be completed. In this context 'Force Majeure' means damage to the ship, unforeseen inability of Surveyors to attend the ship due to governmental restrictions on right of access or movement of personnel, unforeseen delays in port or inability to discharge cargo due to unusually lengthy periods of severe weather, strikes, civil strife, acts of war or other force majeure.

3.10.2 In circumstances of global disruption to normal maritime operations, such as experienced during the global COVID-19 pandemic, where Flag Administrations adopt extraordinary measures permitting postponements to scheduled statutory surveys beyond the due dates, the Classification Committee may allow corresponding postponements to scheduled class surveys provided the following measures to confirm the continued compliance of the vessel with LR classification requirements are undertaken:

(a) a confirmatory LR examination of the ship’s records; and,
(b) an LR review of evidence submitted by the Owner that confirms that the vessel is in a condition to satisfactorily continue in class for the agreed period of postponement; this may include an LR remote survey, and provision to LR of acceptable photographic, video or other evidence of condition of structure or equipment; and,
(c) receipt of a confirmatory statement from the Master advising that the ship is, in their opinion, in compliance with LR’s *Rules and Regulations* and in a condition to satisfactorily continue in service for the agreed period; and,
(d) any due and/or overdue surveys and examination of Conditions of Class, Actionable Items and Statutory Findings are to be carried out at the first port of call with available facilities where LR Surveyors can reasonably attend to complete the overdue surveys.

3.11 Ownership details

3.11.1 The Owner will ensure a member of the LR Group - Marine and Offshore division is promptly informed in writing of any change to their contact details and, in the event of a vessel/asset transfer or sale, is to supply details of the new Owner in writing. The new Owner is to promptly inform a member of the LR Group - Marine and Offshore division in writing of their contact details. If the new Owner fails to do so and if LR cannot verify the ownership record, then the class of that vessel/asset will be specially considered by the Classification Committee.

Section 4
Type Approval/Type Testing/ Quality Control System

4.1 LR Type Approval – Marine application

4.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or, where testing is not appropriate, a design analysis.

4.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to be able to use Quality Control procedures and processes to ensure that each item delivered is in conformity with that which has been Type Approved.

4.1.3 The selective testing required is to include environmental testing applicable to the product's installation on board a ship classed or intended to be classed with LR.

4.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in ships classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

4.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Inland Waterway Ships are fulfilled.

4.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with *Pt 1, Ch 2, 5.3 Survey and inspection*.

4.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

4.2 Type testing

4.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

4.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

4.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

4.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

4.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where the previous testing is in compliance with the current testing standards for the equipment.

4.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

4.3 Quality Control System

4.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities which is used to demonstrate that the quality requirements for a product are in accordance with declared standards.

4.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

4.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The

purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

4.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of a quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 5*
Classification of machinery with [✠]LMC or MCH notation

5.1 General

5.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the shipyard, the Survey at the Shipyard the and Periodical Surveys are to be in accordance with the requirements for ships built with the ✠ **LMC** notation.

5.2 Appraisal and records

5.2.1 To facilitate survey and compilation of classification records, the same plans and information required for a ship being accepted into class with the ✠ **LMC** notation are to be submitted for the alternative notations [✠] **LMC** or **MCH**, for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of the previous type approval.

5.3 Survey and inspection

5.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the [✠] **LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

5.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a ship having the ✠ **LMC** notation.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys*. The intervals between such surveys are as follows:

(a) Annual Surveys at yearly intervals as required by *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.1* or *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.2*.
(b) Intermediate Surveys at intervals of 30 months, *see Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.3*.
(c) Special Surveys at five-yearly intervals, *see Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.4* and *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.9*.
(d) Complete Surveys of machinery at five-yearly intervals, *see Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.11* and *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.15*.
(e) Consideration will be given to alternative periods between surveys where these are specified by local Administration or Authority Regulations for inland waterways vessels that trade solely within their jurisdictions.

1.1.2 For the frequency of surveys of boilers *see Pt 1, Ch 3, 13 Boilers*.

1.1.3 For the frequency of surveys of steam pipes, *see Pt 1, Ch 3, 14 Steam pipes*.

1.1.4 For the frequency of surveys of screwshafts, tube shafts and propellers, *see Pt 1, Ch 3, 15 Screwshafts, tube shafts and propellers*.

1.1.5 For the frequency of surveys of inert gas systems, *see Pt 1, Ch 3, 16 Inert gas systems*.

1.1.6 For ships assigned the notation 'laid up', in order to maintain the ship in class a general examination of the hull and machinery is to be carried out in lieu of the Annual Survey/Intermediate Survey and in addition an Underwater Examination (UWE) is to be carried out in lieu of the Special Survey.

1.2 Surveys for damage or alterations

1.2.1 At any time when a ship is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the propulsion or auxiliary machinery, including boilers, insulation or fittings, and tanks not forming part of the ship's structure, is removed for any reason, the steel structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed, the plating in way is to be examined before the cement or covering is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any ship, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar ships classed by LR and deemed to be vulnerable.

1.4 Definitions

1.4.1 A **Tanker** is a self-propelled ship or a non-propelled ship (barges) which is constructed generally with integral tanks and is intended primarily to carry liquids in bulk. *See Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*.

1.4.2 A **Bulk Carrier** is a self-propelled ship or a non-propelled ship (barge) intended for the carriage of dry bulk cargoes. *See Pt 4, Ch 1 Dry Cargo Ships*.

1.4.3 A **Container Ship** is a self-propelled ship or a non-propelled ship (barge) intended for the carriage of containers. *See Pt 4, Ch 1 Dry Cargo Ships*.

1.4.4 A **Chemical Tanker** is a self-propelled ship or a non-propelled ship (barge) constructed generally with integral tanks and being double hull construction, used primarily for the carriage of chemicals in bulk. *See Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk* and *Pt 4, Ch 6 Tankers of Types C and N*.

1.4.5 A **Gas Tanker** is a cargo ship designed, constructed and used for the carriage in bulk of liquefied gases or other liquid products of a flammable nature. *See Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk* and *Pt 4, Ch 5 Tankers of Type G*.

1.4.6 A **Ballast Tank** is a tank which is used solely for the carriage of water ballast.

1.4.7 **Spaces** are separate compartments such as holds, tanks, cofferdams and void spaces bounding cargo holds, decks and the outer hull.

1.4.8 An **Enclosed space** is any place of an enclosed nature where there is a risk of death or serious injury from hazardous substances or dangerous conditions. Examples include, but are not limited to: boilers, pressure vessels, cargo spaces (cargo holds or cargo tanks), cargo space stairways, ballast tanks, double bottoms, double hull spaces, fuel oil tanks, lube oil tanks, sewage-tanks, pump-rooms, compressor rooms, cofferdams, void spaces, duct keels, inter-barrier spaces, engine crankcases, excavations and pits.

1.4.9 An **Overall Survey** is a survey intended to report on the overall condition of the hull structure, if required.

1.4.10 A **Transverse Section** includes all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom, inner bottom, inner side, hopper side, top wing side and longitudinal bulkhead, where fitted. For transversely framed ships, a transverse section includes adjacent frames and their end connections in way of transverse sections.

1.4.11 **Suspect Areas** are locations which have been identified from calculations to require monitoring or from the service history of the subject ship or from similar ships or sister ships, if applicable, to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship.

1.4.12 A **Hard Coating** is one that cures dry and hard. This is usually to be an epoxy coating or equivalent. Other systems (e.g. soft coatings) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.4.13 **Coating Condition** is defined as follows:

GOOD	condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration, e.g. on a deck transverse, side transverse, on the total area of platings and stiffeners on the longitudinal structure between these components, etc.
FAIR	condition with local breakdown at edges of stiffeners and weld connections and/or light rusting affecting 20 per cent or more of areas under consideration.
POOR	condition with general breakdown of coating affecting 20 per cent or more of areas under consideration or hard scale affecting 10 per cent or more of area under consideration.

1.4.14 A **Prompt and Thorough Repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, thereby removing the need for the imposition of any associated condition of class.

1.4.15 The **Cargo Length Area** is that part of the ship which contains all cargo holds and adjacent areas including fuel tanks, cofferdams, ballast tanks and void spaces. For oil tankers and chemical tankers, the **Cargo Length Area** is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump-rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above mentioned spaces.

1.5 Preparation for survey and means of access

1.5.1 Tanks and spaces are to be safe for access, i.e. gas freed, ventilated and illuminated.

1.5.2 In preparation for survey, thickness measurements and to allow for a thorough examination, all spaces are to be cleaned including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc. to reveal corrosion, deformation, fractures, damages or other structural deterioration. However, those areas of structure whose renewal has already been decided by the owner need only be cleaned and descaled to the extent necessary to determine the limits of areas to be renewed.

1.5.3 Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.

1.5.4 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way.

1.5.5 For surveys, including close-up survey where applicable, in cargo spaces and ballast tanks, one or more of the following means of access is to be provided:

(a) Permanent staging and passages through structures.
(b) Temporary staging and passages through structures.
(c) Hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms.
(d) Boats or rafts, provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water.
(e) Portable ladders may be used, at the discretion of the Surveyor.
(f) Other equivalent means.

1.5.6 Where soft coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft coating is to be removed.

1.5.7 A survey planning meeting is to be held prior to the commencement of the Intermediate Survey and Special Survey.

1.6 Repairs

1.6.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;

- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings.

For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.6.2 Additionally, when a survey results in the identification of structural defects or corrosion, either of which, in the opinion of the Surveyor, will impair the ship's fitness for continued service, remedial measures are to be implemented before the ship continues in service.

■ *Section 2* Annual Survey – Hull requirements

2.1 Preparation

2.1.1 The ship is to be arranged and prepared for examination as required by *Pt 1, Ch 3, 2.2 Examination and testing for ships which are to be subjected to Annual Surveys as set out in Ch 2,3.5.1* or *Pt 1, Ch 3, 2.3 Examination and testing for ships which are subjected to Annual Surveys as set out in Ch 2,3.5.2* as applicable.

2.2 Examination and testing for ships which are to be subjected to Annual Surveys as set out in Ch 2,3.5.1

2.2.1 The Surveyor is to be satisfied as to the efficient condition of the following:

(a) Hatchways on freeboard and superstructure decks, ventilator and air pipe coamings, exposed casings, skylights, deck-houses and companionways, superstructure bulkheads, side scuttles and deadlights, together with all closing appliances.
(b) Means of ensuring weathertightness of steel hatch covers by hose test if deemed necessary.
(c) Scuppers and sanitary discharges with valves.
(d) Guard rails and bulwarks, freeing ports, gangways and life-lines.
(e) Freeboard marks.
(f) Steering arrangements.
(g) Vent piping, including that of inert gas installations, where applicable, within the cargo tank area, together with associated flame arresters and pressure/vacuum valves.
(h) Cargo and bunker deck piping of tankers.

2.2.2 On tankers of Type G, C and N, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*, *Pt 4, Ch 5 Tankers of Type G* and *Pt 4, Ch 6 Tankers of Types C and N*, when submitted for the survey required by *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.7*, pump-rooms and the electrical installation are also to be inspected, including verification of:

(a) The efficiency of any safe type equipment fitted.
(b) The insulation resistance.
(c) Tests carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

Inert gas installations are to be examined in accordance with *Pt 1, Ch 3, 16 Inert gas systems*.

2.3 Examination and testing for ships which are subjected to Annual Surveys as set out in Ch 2,3.5.2

2.3.1 Surveyors are to examine the ship afloat in light condition internally and externally, as far as necessary in order to satisfy themselves as to the efficient condition of the hull structure.

2.3.2 Should examination afloat give rise to doubts as to the condition of the underwater structure or of tanks and cofferdam spaces, it may be necessary for Surveyors to require the ship to be dry-docked or placed on a slipway for a more detailed inspection.

2.3.3 Where the ship is placed in dry dock or on a slipway, Surveyors are to examine the shell plating, the sternframe, rudder(s), etc. and attention is to be given to those underwater parts of the ship particularly liable to deterioration due to excessive corrosion or to damage by contact with other vessels, quay walls or from causes such as chafing, touching or lying on the ground and to any undue unfairness of bottom plating especially in transversely framed ships.

2.3.4 Surveyors are to satisfy themselves as to the efficient condition of the following, where applicable:

(a) Hatchways with beams and covers, deck-houses and companionways together with any closing appliances.
(b) Scuppers and sanitary discharges so far as practicable, bulwarks and guard rails.

2.3.5 Surveyors are to examine the steering arrangements. The various parts of the auxiliary steering gear are to be assembled to ascertain that the gear is in good and workable condition. Auxiliary steering gear of the mechanically driven type is to be examined and tested to demonstrate that, if the power for the main steering gear fails, the auxiliary gear can be put into operation immediately.

2.3.6 Surveyors are to examine and test bow rudder installations when they are an essential part of the steering arrangement. Opening up the gear may be required if deemed necessary by Surveyors in view of the condition or the testing of the gear.

2.3.7 When chain cables are ranged, the anchors and cables are to be examined by the Surveyors.

2.3.8 Surveyors are to satisfy themselves as to the efficient condition of the fire protection, detection and extinguishing arrangements so far as applicable.

■ *Section 3*
Intermediate Survey – Hull requirements

3.1 Preparation

3.1.1 The ship is to be brought into light condition for internal and external examination afloat.

3.1.2 The following ships are to be examined in dry-dock or on a slipway:

(a) Ships which are riveted below the light waterline.
(b) Ships over 20 years old.

In the case of ships over 20 years old and not riveted below the light waterline this requirement may be waived if following an internal examination the Surveyor is satisfied as to the efficient condition of the underwater part of the shell.

3.1.3 When the ship is in dry dock or on a slipway, it is to be at a sufficient height above the dock floor or the ground for examination of shell plating, sternframe, rudder(s), etc. If necessary proper staging is to be erected for this examination. On side slipways it may be required to remove cradles for examination of the bottom plating. Each rudder is to be lifted for examination of pintles if considered necessary by the Surveyor.

3.1.4 The decks, hatchways with beams and covers are to be cleared for examination.

3.1.5 The steering gear and auxiliary steering gear are to be prepared for examination and testing.

3.1.6 Tankers of Type G, C and N, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*, when submitted for the survey required by *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.7*, are to be thoroughly cleared of gas.

3.1.7 Stream anchor, when provided, is to be prepared for examination and testing.

3.2 Examination and testing

3.2.1 The requirements of *Pt 1, Ch 3, 2 Annual Survey – Hull requirements* and *Pt 1, Ch 3, 10.1 Annual Surveys* are to be complied with so far as applicable.

3.2.2 The Surveyor is to examine the ship afloat in light condition internally and externally, for so far as necessary in order to satisfy himself as to the efficient condition of the hull structure.

3.2.3 Should examination afloat give rise to doubts as to the condition of the underwater structure or of tanks and cofferdam spaces, it may be necessary for the Surveyor to require the ship to be dry-docked or placed on a slipway for a more detailed inspection.

3.2.4 When the ship is placed in dry dock or on a slipway, the Surveyor is to examine the shell plating, the sternframe, rudder(s), etc. and attention is to be given to those underwater parts of the ship particularly liable to deterioration due to excessive corrosion or to damage by contact with other vessels, quay walls or from causes such as chafing, touching or lying on the ground and to any undue unfairness of bottom plating, especially in transversely framed ships.

3.2.5 The Surveyor is to be satisfied as to the efficient condition of the following, where applicable:

(a) Hatchways with beams and covers, deck houses and companionways together with any closing appliances.
(b) Scuppers and sanitary discharges so far as practicable.
(c) Bulwarks and guard rails.
(d) Wheelhouse elevation arrangements.

3.2.6 The Surveyor is to examine the steering arrangements. The various parts of the auxiliary steering gear are to be assembled to ascertain that the gear is in good and workable condition. Auxiliary steering gear of the mechanically driven type is to be examined and tested to demonstrate that, if the power for the main steering gear fails, the auxiliary gear can be put into operation immediately.

3.2.7 Where rod and chain steering gear is fitted, attention is to be paid to all parts of rod and chain gears. All pins are to be examined and the chain in the vicinity of the blocks is to be cleaned and examined for wear and tear. Any length of chain so worn that its mean diameter at its most worn part is reduced by 12 per cent or more from its Rule diameter, is to be renewed. All replacements of chains are to be subjected, at a recognised Proving Establishment, to the proof tests required for short link cables by *Ch 10 Equipment for Mooring and Anchoring* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*, and the certificates are to be produced. It is recommended that, in addition, a breaking test be applied to these chains.

3.2.8 It is recommended that repaired chains be tested by the repairers and a certificate to that effect produced.

3.2.9 The Surveyor is to examine and test bow rudder installations when they are an essential part of the steering arrangement. Opening up the gear may be required if deemed necessary by the Surveyor in view of the condition or the testing of the gear.

3.2.10 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor.

3.2.11 The Surveyor is to satisfy himself as to the efficient condition of the fire protection, detection and extinguishing arrangements so far as applicable.

3.2.12 On tankers of Type G, C and N Closed and N open with flame screens, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*, *Pt 4, Ch 5 Tankers of Type G* and *Pt 4, Ch 6 Tankers of Types C and N*, pump-rooms, cargo, bunker and vent piping systems on deck and in pumprooms, pressure/vacuum valves and flame arresters and the electrical installation are also to be inspected, including verification of:

(a) The efficiency of any safe type equipment fitted.
(b) The insulation resistance.
(c) Tests are to be carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

Inert gas installations are to be examined in accordance with *Pt 1, Ch 3, 16 Inert gas systems*.

■ *Section 4*
Special Survey – Hull requirements

4.1 Preparation

4.1.1 The ship is to be placed in dry dock or on a slipway, cleaned and be at a sufficient height above the dock floor or the ground for examination of shell plating, sternframe, rudder(s), etc. If necessary, proper staging is to be erected for this examination. On side slipways it may be required to remove cradles for examination of the bottom plating. Each rudder is to be lifted for examination of pintles if considered necessary by the Surveyor.

4.1.2 The holds, peaks, deep and wing tanks, engine and boiler spaces, and other spaces, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination as required by *Pt 1, Ch 3, 4.2 Examination and testing*. Platform plates in engine and boiler spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, close and spar ceiling, lining and pipe casings are to be removed for examination of the structure.

4.1.3 In ships having a single bottom, a sufficient amount of close ceiling is to be lifted on each side from the bottom and bilges to permit the structure below to be examined.

4.1.4 In ships having a double bottom, a sufficient amount of ceiling is to be removed from the bilges and inner bottom to enable the condition of the plating to be ascertained. If it is found that the plating is clean and in good condition, and free from rust, the removal of the remainder of ceiling may be dispensed with. The Surveyor may waive the removal of heavy reinforced compositions if there is no evidence of leakages, cracking or other faults in the composition.

4.1.5 The steelwork is to be exposed and cleaned as may be required for its proper examination by the Surveyor.

4.2 Examination and testing

4.2.1 The requirements of an Intermediate Survey are to be complied with, *see Pt 1, Ch 3, 3 Intermediate Survey – Hull requirements*.

4.2.2 All items and spaces required to be cleared and cleaned for examination by *Pt 1, Ch 3, 4.1 Preparation* are to be examined. Careful examination is to be made of parts of the structure particularly liable to excessive corrosion, or to deterioration from causes such as chafing, lying on the ground, or handling of cargo.

4.2.3 The Surveyor may require to gauge, by ultrasonic thickness measurement or other approved means, the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or materially reduced in scantlings are to be made good by materials of approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be re-coated as necessary.

4.2.4 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.

4.2.5 Double bottom tanks, peak tanks and all other tanks are to be tested by a head sufficient to give the normal maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat. Tanks forming part of the main structure, except as stated below, are to be cleaned and examined internally, special attention being given to tanks under boiler spaces. Tanks (excluding peak tanks) used exclusively for fuel oil or fresh water in ships less than 15 years old need not be examined internally, provided that, after external examination and testing in accordance with the requirements set out above, the Surveyor finds the condition of these compartments satisfactory.

4.2.6 Spaces which are inaccessible for examination, e.g. low double bottom tanks, boxed in webframes, spaces under tanks not forming part of the ship's structure are to be examined externally and gauged as necessary. In case of doubt, openings are to be made in the structure for examination of the interior so that the Surveyor can be satisfied as to the efficient condition of the structure.

4.2.7 All decks, casings and superstructures are to be examined. Attention is to be given to the corners of openings and other discontinuities in way of strength decks and top sides.

4.2.8 Wood decks or sheathing are to be examined. If decay or rot is found or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed, as necessary, to ascertain the condition of the plating. *See also Pt 1, Ch 3, 1.2 Surveys for damage or alterations 1.2.1*.

4.2.9 The anchors are to be examined. If the chain cables are ranged they are to be examined. Chain cables of ships over 10 years old are to be ranged at each Special Survey. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

4.2.10 The Surveyor is to satisfy himself that there are suitable mooring ropes and a towline when these are a Rule requirement.

4.2.11 The steering gear, and its connections and control systems (main and alternative) are to be examined. The various parts of the auxiliary steering gear are to be assembled, examined and tested. The helm indicator is to be examined and tested.

4.2.12 The hand pumps, suctions, watertight doors, air and sounding pipes are to be examined.

4.2.13 The Surveyor is to satisfy himself as to the efficient condition of the following:

(a) Means of escape from: machinery spaces, crew and passenger spaces, and spaces in which crew are normally employed.
(b) Means of communication between: bridge and engineroom control station.
(c) Fire protection, detection and extinction.

4.2.14 For surveys of machinery, electrical equipment, boilers, steam pipes, screwshafts and inert gas systems, *see Pt 1, Ch 3, 10 Machinery surveys – General requirements*.

4.2.15 The sea connections, scuppers and sanitary discharges, and their attachments to the hull and the gratings at the sea inlets are to be examined. Ship side valves (i.e. sea connections, scuppers and sanitary discharges) are to be tested once reassembled.

4.3 Thickness measurements

4.3.1 The general minimum requirements for thickness measurements for all ship types are given in *Table 3.4.1 Thickness measurements - All ship types*. The Surveyor may extend the thickness measurements as deemed necessary.

Table 3.4.1 Thickness measurements - All ship types

Special Survey I (Ships 5 years old)	**Special Survey II** (Ships 10 years old)	**Special Survey III** (Ships 15 years old)	**Special Survey IV** (Ships 20 years old and over)
Suspect Areas, as required by the Surveyor, *see* **Note 6**	Within the cargo length area or 0,5L amidships: - selected deck plates - one transverse section - selected bottom/inner bottom plates - selected side shell plates - selected hatch covers and coamings, *see* **Note 1**	Within the cargo length area or 0,5L amidships: - each exposed deck plate - two transverse sections - selected tank top plates - each bottom/inner bottom plates - all side shell plates - selected transverse and longitudinal cargo hold bulkheads, *see* **Note 1** - all hatch covers and coamings, *see* **Note 1**	Within the cargo length area or 0,5L amidships: - each deck plate - three transverse sections, *see* **Note 3** - each bottom/inner bottom/tank top plate - all side shell plates - all transverse and longitudinal cargo hold bulkheads, *see* **Note 1** - all hatch covers and coamings, *see* **Note 1**
	Collision bulkhead, forward machinery space bulkhead, aft peak bulkhead, *see* **Notes 1** and **2**	Outside the cargo length area: - selected deck plates - selected side shell plates - selected bottom plates - nozzle plating in way of transverse thrust units	Outside the cargo length area: - each deck plate - each side shell plate - each bottom plate - nozzle plating in way of transverse thrust units
	In engine room, *see* **Note 2**: - sea chests - sea water crossover manifold - duct keel or pipe tunnel plating and internals	Collision bulkhead, forward machinery space bulkhead, aft peak bulkhead, *see* **Notes 1** and **2**	All transverse and longitudinal bulk heads outside cargo hold area, *see* **Notes 1** and **2**

	Suspect Areas, as required by the Surveyor, *see* **Note 6**	In engine room, *see* **Note 2**: - sea chests - sea water crossover manifold - duct keel or pipe tunnel plating and internals	In engine room, *see* **Note 2**: - sea chests - sea water crossover manifold - duct keel or pipe tunnel plating and internals
		Selected internal structure such as ballast tank, floor and longitudinals, transverse frames, web frames, deck beams, girders, etc.	Selected internal structure such as ballast tank, floor and longitudinals, transverse frames, web frames, deck beams, girders, etc.
		Suspect Areas, as required by the Surveyor, *see* **Note 6**	Suspect Areas, as required by the Surveyor, *see* **Note 6**

Note 1. Including plates and stiffeners.

Note 2. Measurements may be waived or reduced after satisfactory visual examination, when such bulkheads form the boundaries of dry void spaces or river chests, etc. are found in good condition.

Note 3. The number of transverse sections may be reduced at the Surveyor's discretion for vessels of length under 40 m.

Note 4. In case of original tank coating being in good condition, or tanks are constructed of stainless steel, scope of TM may be reduced at the Surveyor's discretion.

Note 5. In case of detected areas with substantial corrosion, extent of corrosion should be verified by means of 5 point pattern over one (1) square metre area.

Note 6. Suspect Areas are locations showing substantial corrosion and/or are considered by the Surveyor to be prone to rapid wastage.

4.3.2 Thickness measurements may be carried out in the 12 months preceding the due date of the Special Survey or when the Special Survey is extended as well in the 12 months preceding the revised Special Survey due date.

4.3.3 In areas where substantial corrosion (defined as wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits) has been noted, additional measurements are to be carried out, as deemed necessary by the attending Surveyor.

4.3.4 Where substantial corrosion is identified and not rectified, this will be subject to re-examination and gauging as necessary at Intermediate Surveys.

4.3.5 At each Special Survey, thickness measurements are to be taken in way of Suspect Areas, as considered necessary by the Surveyor. Suspect Areas are to include locations throughout the ship that show substantial corrosion and/or are considered prone to rapid wastage or erosion.

4.3.6 Where a 10 per cent area reduction of deck plating and longitudinals is exceeded, a check of the buckling capacity of the upper deck is to be carried out for all tankers.

■ *Section 5*
Special Survey of ships over 15 years old – Hull requirements

5.1 Preparation

5.1.1 The requirements of *Pt 1, Ch 3, 4.1 Preparation* are to be complied with.

5.1.2 A sufficient amount of ceiling in the holds and other spaces is to be removed from the bilges and inner bottom to enable the condition of structure in the bilges, the inner bottom plating, pillar feet, and the bottom plating of bulkheads to be examined. If the Surveyor deems it necessary, the whole of the ceiling is to be removed.

5.1.3 In ships having a single bottom, the limber boards and ceiling equal to not less than three strakes, all fore and aft on each side are to be removed, one such strake being taken from the bilges and one along the centre keelson. Where the ceiling is

fitted in hatches, the whole of the hatches and at least one strake of ceiling in the bilges are to be removed. If the Surveyor deems it necessary the whole of the ceiling and limber boards are to be removed.

5.1.4 The chain locker is to be cleaned internally. The chain cables are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection.

5.2 Examination and testing

5.2.1 The requirements of *Pt 1, Ch 3, 4.2 Examination and testing* are to be complied with.

5.2.2 All items and spaces required to be cleared and cleaned for examination by *Pt 1, Ch 3, 5.1 Preparation* are to be examined.

5.3 Thickness measurements

5.3.1 The requirements of *Pt 1, Ch 3, 4.3 Thickness measurements* are to be complied with at Special Survey III (Ships 15 years old) and at each Special Survey thereafter.

■ *Section 6*
Special Survey of tankers – Hull requirements

6.1 General

6.1.1 The requirements of *Pt 1, Ch 3, 4 Special Survey – Hull requirements* and *Pt 1, Ch 3, 5 Special Survey of ships over 15 years old – Hull requirements* are to be complied with as applicable.

6.1.2 The survey is to include the inspection of pump-rooms, cargo, bunker and vent piping systems on deck and in pump-rooms, and also pressure/vacuum valves and flame arresters.

6.2 Preparation and inspection of tanks

6.2.1 Attention is to be given to the inside of the bottom plating in order to ensure that there is no excessive pitting of the plating. When extensive pitting is found, care is to be taken to preserve the longitudinal and local strength of the bottom by the requisite renewals or repairs.

6.2.2 When bottom plating and bulkheads in way of strums of cargo suction pipes cannot be properly visually examined, the strums are to be removed for access.

6.2.3 The condition of internal coatings, if applied, is to be examined.

6.3 Testing

6.3.1 All cargo tanks are to be tested by filling the tanks with water to the top of the hatch coaming. Cofferdams and cargo tanks of tankers of Type G, C and N, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*, *Pt 4, Ch 5 Tankers of Type G* and *Pt 4, Ch 6 Tankers of Types C and N*, are to be pressure tested with water to the top of the hatch coaming at odd-numbered Special Surveys (first, third, fifth and so forth). At even-numbered Special Surveys (second, fourth, sixth and so forth) the tanks are to be pressure tested in accordance with the requirements of *Table 1.7.2 Testing requirements* in *Pt 3, Ch 1, 7.3 Acceptance testing on completion*.

6.3.2 Tanks may be tested when the ship is afloat, provided that the internal examination of the bottom is also carried out afloat.

6.3.3 Where extensive repairs have been effected to the shell plating or bulkheads, the tanks are to be tested to the Surveyor’s satisfaction.

6.4 Thickness measurements

6.4.1 The requirements of *Pt 1, Ch 3, 4.3 Thickness measurements* are to be complied with at Special Surveys.

Section 7
Special Survey of tankers with cargo tanks independent from the ship's structure – Hull requirements

7.1 General

7.1.1 The requirements of *Pt 1, Ch 3, 4 Special Survey – Hull requirements* and *Pt 1, Ch 3, 5 Special Survey of ships over 15 years old – Hull requirements* and of *Pt 1, Ch 3, 6.1 General 6.1.2*, *Pt 1, Ch 3, 6.2 Preparation and inspection of tanks 6.2.2* and *Pt 1, Ch 3, 6.2 Preparation and inspection of tanks 6.2.3* are to be complied with so far as applicable.

7.2 Preparation and inspection

7.2.1 Special attention should be paid to the ship's structure underneath the cargo tanks and the supports, chocking and securing arrangements, etc. of these tanks.

7.3 Testing

7.3.1 All cargo tanks are to be tested by filling the tanks with water to the top of the hatch coaming or equivalent method. Cofferdams and cargo tanks of tankers of Type G, C and N, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*, *Pt 4, Ch 5 Tankers of Type G* and *Pt 4, Ch 6 Tankers of Types C and N*, are to be pressure tested with water to the top of the hatch coaming at odd-numbered Special Surveys (first, third, fifth and so forth). At even-numbered Special Surveys (second, fourth, sixth and so forth) the tanks are to be pressure tested in accordance with the requirements of *Table 1.7.2 Testing requirements* in *Pt 3, Ch 1, 7.3 Acceptance testing on completion*.

7.4 Thickness measurements

7.4.1 The requirements of *Pt 1, Ch 3, 4.3 Thickness measurements* are to be complied with for the hull structure at each Special Survey. Cargo tanks independent from the ship's structure are to be gauged, by ultrasonic thickness measurement or other approved means, to determine the amount of general diminution in thickness. The gauging is to be done in at least one place on each tank (in two places on each tank over 20 m in length) in each strake of bottom, forward and aft side and top plating. The remainder of the plating is to be gauged as deemed necessary by the Surveyor, taking into account the results of gauging already carried out.

Section 8
Ships for liquefied gases under pressure and/or partially refrigerated

8.1 Annual Surveys

8.1.1 The requirements of *Pt 1, Ch 3, 2 Annual Survey – Hull requirements* are to be complied with as applicable.

8.1.2 The requirements of *Pt 1, Ch 3, 10.1 Annual Surveys* for machinery are to be complied with as applicable.

8.1.3 The Annual Survey requirements of *Pt 1, Ch 3, 12.2 Annual and Intermediate Surveys* for electrical equipment are to be complied with as applicable.

8.2 Intermediate Surveys – General requirements

8.2.1 Cargo liquid level indicating devices are to be generally examined. The low level, high level and overfill alarms are to be examined and tested to ascertain that they are in working order. Consideration will be given to the acceptance of simulated tests provided that they are carried out at the cargo temperature and/or pressure.

8.2.2 Where applicable, gas leakage systems are to be examined and tested to ascertain that they are in working order and calibrated using sample gas.

8.2.3 Where applicable, the correct functioning of the cargo containment system temperature indicating equipment, together with any associated alarms, is to be verified.

8.2.4 Where applicable, the ventilation system for the spaces surrounding the cargo tanks and in working spaces is to be examined and checked for satisfactory operation.

8.2.5 Where applicable, inert gas systems for the environmental control of cargo tanks and/or spaces surrounding the cargo tanks are to be generally examined.

8.2.6 Where applicable, control devices for the cargo containment system and cargo handling equipment, together with any associated shut-down and/or interlock, are to be checked under simulated working conditions, and if required, recalibrated.

8.2.7 The arrangements for manually operated emergency shut-down are to be checked to ascertain they are in working order.

8.2.8 Cargo pipelines, valves and fittings are to be generally examined, with special reference to expansion bellows, supports and vapour seals on insulated pipes.

8.2.9 Portable and/or fixed drip trays, or insulation for deck protection in the event of cargo leakage are to be examined for their condition.

8.3 Intermediate Surveys – Refrigerating equipment

8.3.1 Where refrigerating equipment for cargo temperature and pressure control is fitted the following are to be examined so far as practicable:

(a) The machinery under working conditions.
(b) Shells of all pressure vessels in the system including primary refrigerant gas and liquid pipes, cargo vapour and liquid condensate pipes and condenser cooling arrangements. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated.

8.4 Special Surveys – General requirements

8.4.1 For requirements of Special Survey for electrical equipment, *see Pt 1, Ch 3, 12 Electrical equipment*

8.4.2 All cargo tanks are to be examined internally and externally so far as practicable, particular attention being paid to the plating in way of supports and of chocking and securing arrangements and pipe connections.

8.4.3 Where cargo tanks are insulated and the insulation accessible, the insulation should be examined externally and sections removed for examination of the tank if considered necessary by the Surveyor.

8.4.4 The Surveyor may require to gauge, by ultrasonic thickness measurement or other approved means, the thickness of the material in any portion of the cargo tank structure where sign of wastage is evident, wastage is normally found or where there is doubt as to the condition of the structure in way of insulation. Any parts of the cargo tank structure which are found defective or materially reduced in scantlings are to be made good by materials of approved scantlings and quality.

8.4.5 Cargo tank internal pipes and fittings are to be examined, and all valves and cocks in direct communication with the interiors of tanks are to be opened out for inspection and connection pipes are to be examined internally, so far as practicable.

8.4.6 Pressure relief valves and vacuum relief valves are to be opened out for inspection and are to be adjusted afterwards. Valves may be removed from tanks, cargo gas and liquid pipelines for this purpose.

8.4.7 All cargo pumps, cargo booster pumps and cargo vapour pumps, where applicable, are to be opened out for examination.

8.4.8 Where considered necessary by the Surveyor, insulated cargo gas and liquid pipelines are to have sections of insulation removed to ascertain the condition of the pipes.

8.4.9 Where equipment for the production of inert gas is fitted, it is to be examined and tested to show it to be operating satisfactorily within the gas specification limits. Pipelines, valves, etc. for the distribution of the inert gas are to be generally examined. Pressure vessels for the storage of inert gas are to be examined internally together with their fastenings. Pressure relief valves are to be demonstrated to be in good working order. Liquid nitrogen storage vessels are to be examined as far as practicable and all control equipment, alarms and safety devices are to be verified as operational.

8.5 Special Surveys – Refrigerating equipment

8.5.1 Each reciprocating compressor is to be opened out. Cylinder bores, pistons, piston rods, connecting rods, valves and seats, glands, relief devices, suction filters and lubricating arrangements are to be examined. Crankshafts are to be examined but

crankcase glands and the lower half of main bearings need not be exposed if the Surveyor is satisfied with the alignment and wear.

8.5.2 Where other than reciprocating type compressors are fitted, or where there is a program of replacement instead of surveys on board, alternative survey arrangements will be considered. Each case will be given individual consideration.

8.5.3 The water end covers of condensers are to be removed for examination of the tubes, tubeplates and covers.

8.5.4 Refrigerant condenser cooling water pumps, including standby pump(s) which may be used on other services, are to be opened out for examination.

8.5.5 Where a pressure vessel is insulated, sufficient insulation is to be removed, especially in way of connections and supports, to enable the vessel's condition to be ascertained.

8.5.6 Insulated pipes are to have sufficient insulation removed to enable their condition to be ascertained. Vapour seals are to be specially examined for condition.

8.5.7 The Surveyor is to satisfy himself that all pressure relief valves and/or safety discs throughout the system are in good order. No attempt, however, is to be made to test primary refrigerant pressure relief valves on board ship.

8.6 Special Surveys of ships over 10 years old

8.6.1 The requirements of *Pt 1, Ch 3, 8.1 Annual Surveys* are to be complied with so far as applicable.

8.6.2 All pressure vessels of inert gas installations are to be examined internally and externally and tested.

8.6.3 Cargo tanks are to be pressure tested to a pressure of 1,25 times the working pressure.

8.7 Thickness measurement of tank plating

8.7.1 In addition to the requirements of *Pt 1, Ch 3, 8.4 Special Surveys – General requirements 8.4.4*, thickness measurement of cargo tank plating is to be carried out at each Special Survey by ultrasonic thickness measurement or other approved means, to determine the amount of any general diminution. The gauging is to be carried out in at least two places of the bottom, forward and aft tank plating, side and top plating. The remainder of the plating is to be gauged as deemed necessary by the Surveyor, taking into account the results of gauging already carried out.

■ *Section 9*
Dredgers, hopper dredgers, sand carriers, hopper barges and reclamation craft

9.1 General

9.1.1 The requirements of this Section are to be complied with, as applicable, in addition to the survey requirements of *Pt 1, Ch 3, 2 Annual Survey – Hull requirements*. Where surveys are required on dredging or hopper equipment such as gantries, bottom doors and their operating gear, positioning spuds and suction pipe attachments, these will be limited to the extent considered necessary by the Surveyor to be satisfied that their condition or malfunction will not adversely affect the ship's structure.

9.1.2 When the ship is placed in dry dock or on a slipway, the Surveyor is to examine the hopper doors or hopper valves, ladders, spudwells, and their fittings where applicable.

9.2 Special Surveys

9.2.1 On ships under 10 years old:

(a) Hoppers are to be cleared and cleaned as necessary and examined.
(b) Where applicable, hopper doors or valves are to be opened and closed, so far as is practicable, but keel blocks need not normally be moved specially to permit this to be done.
(c) The integrity of hopper overflows and diluting water inlet and distribution structures are to be confirmed. Weir valves and sluices are to be tested to ensure proper operation, particular attention being paid to the lower weir, when weirs are fitted at more than one level.
(d) Attention is to be given to shell plating in way of hopper overflows.

(e) The attachment to the ship's structure of all main items of dredging equipment, including gantries, 'A' frames and spud control gear supports, is to be carefully examined to ensure that no fracture or other damage is present.

9.2.2 On ships over 10 years old:

(a) Attention is to be given by the Surveyor to the structure in way of dredging pumps.
(b) Hopper doors and valves are to be checked for proper operation, and their hinges, control gear and other fittings are to be examined for wear or distortion. All seals and weardown strips are to be replaced if necessary, but a watertight seal is not normally required. Attention is to be paid to areas likely to be suffering from excessive erosion.
(c) Those items of dredging gear and equipment whose efficiency is not part of classification but whose failure or malfunctioning is, nevertheless, likely to affect the ship's structure adversely, are to be examined to ensure that the structural integrity of the ship is maintained.

9.3 Thickness measurement

9.3.1 The requirements of *Pt 1, Ch 3, 4.3 Thickness measurements* are to be complied with at each Special Survey.

■ *Section 10*
Machinery surveys – General requirements

10.1 Annual Surveys

10.1.1 In ships which are to be subjected to Annual Surveys as set out in *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys* and are placed in dry dock or on a slipway, *see Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.7*, the propeller(s), sternbush(es), water inlets and outlets and gratings are to be examined. The clearance in each sternbush or the efficiency of each sterngland is to be ascertained.

10.1.2 In ships which are subject to Annual Surveys as set out in *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.2* the Surveyor is to inspect the machinery spaces generally, with particular attention being given to the following:

(a) Propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards.
(b) Emergency escape routes are to be checked to ensure that they are free of obstruction.
(c) The bilge pumping system, including operation of extended spindles and level alarms, where fitted. Satisfactory operation of the bilge pumps is to be proven.
(d) Verification, so far as is practicable, that the remote controls for stopping fans and machinery and shutting off fuel oil supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.

10.1.3 For additional requirements for tankers, *see Pt 1, Ch 3, 2.2 Examination and testing for ships which are to be subjected to Annual Surveys as set out in Ch 2,3.5.1 2.2.2*.

10.1.4 The main propulsion, essential auxiliary and emergency generators including safety arrangements, controls and foundations are to be generally examined. Surveyors are to confirm that Periodical Surveys of engines have been carried out as required by the Rules and that safety devices have been tested.

10.1.5 For ships fitted with automation equipment for main propulsion, essential auxiliary and emergency machinery, a general examination of the equipment and arrangements is to be carried out. Records of changes to the hardware and software used for control and monitoring systems for propelling and essential auxiliary machinery since the original issue (and their identification) are to be reviewed by the attending Surveyor. Satisfactory operation of the safety devices and control systems is to be verified.

10.1.6 For ships fitted with an electronically controlled engine for main propulsion, essential auxiliary and emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) A general examination of the electronic control system and associated parts.
(b) Verification of evidence of satisfactory operation of the engine and where possible this is to include a running test under load.
(c) Verification of satisfactory operation of the safety devices and control systems.
(d) Verification that any changes to hardware and software for control of the engine have been submitted and approved by LR.
(e) Verification that any changes to control and monitoring arrangements that affect the operation of the engine have been submitted and approved by LR.

(f) Verification that where changes have been carried out, there is evidence of acceptance tests and trials for Programmable Electronic Systems which include confirmation of software life cycle activities appropriate to the stage in the system's life cycle at the time of system examination.
(g) Identification and verification that the key monitoring parameters/sensors are in working order.

10.2 Intermediate Surveys

10.2.1 In ships which are placed in dry dock or on a slipway for this survey, the propeller(s), sternbush(es), water inlets and outlets and gratings are to be examined. The clearance in each sternbush or the efficiency of each sterngland is to be ascertained.

10.2.2 The machinery installation is to be generally examined and tested under full load working conditions.

10.2.3 For additional requirements for tankers, *see Pt 1, Ch 3, 3.2 Examination and testing 3.2.12*.

10.2.4 For ships fitted with a classed dynamic positioning system, the control system and associated machinery items are to be generally examined under working conditions.

10.3 Complete Survey of machinery

10.3.1 When the ship is in dry dock or on a slipway, the propeller(s), sternbush(es), water inlets and outlets and gratings are to be examined. The clearance in each sternbush or the efficiency of each oil gland is to be ascertained.

10.3.2 All shafts (except screwshafts and tube shafts for which special arrangements are detailed in *Pt 1, Ch 3, 15 Screwshafts, tube shafts and propellers*), thrust block(s) and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and weardown can be established and found to be within acceptable limits.

10.3.3 An examination is to be made of all reduction gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and integral clutch arrangements. Toothed parts and clutches may be checked through inspection doors. Opening up may be required by the Surveyor in view of the visible condition of the components.

10.3.4 The following auxiliaries and components are to be examined under working conditions:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass(es) and associated driving equipment, where fitted. Opening up may be required by the Surveyor depending upon the trial results or the visible condition of the components.

10.3.5 The holding down bolts and chocks of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings are to be examined.

10.3.6 All air receivers for essential services, together with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

10.3.7 The valves, cocks and strainers of the bilge system are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The fuel oil, feed, lubricating oil and cooling water systems, also the ballast connections and blanking arrangements to deep tanks which may carry liquid or dry cargoes, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

10.3.8 Fuel tanks which do not form part of the ship’s structure are to be examined and if it is considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally before the ship is 15 years old if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all fuel tanks are to be examined, so far as practicable.

10.3.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

10.3.10 Detailed requirements for engines, electrical installations and boilers are given in *Pt 1, Ch 3, 11 Engines – Detailed requirements*, *Pt 1, Ch 3, 12 Electrical equipment* and *Pt 1, Ch 3, 13 Boilers*, respectively. In certain instances, upon application by the Owner or where indicated by the maker’s servicing recommendations, the Surveyor will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking into account design, appropriate indicating equipment and operational records.

10.3.11 For tankers the cargo vapour detection and alarm systems are to be examined, calibrated and tested to demonstrate that they are in good working order. Upper deck cargo loading and discharge pipe lines are to be subjected to a pressure test of 1,1 times the approved maximum working pressure with a minimum of 10 Bar.

10.3.12 For ships that are provided with wheelhouse elevation arrangements, these arrangements are to be examined and tested to the extent as considered necessary by the Surveyor.

10.3.13 On vessels fitted with a classed dynamic positioning system, the control system and associated machinery items are to be examined and tested under working conditions.

10.3.14 Where Thrusters and/or Podded Propulsors are fitted and have been assigned the ShipRight descriptive note **ThCM**, the degree of inspection required whilst in dock will be determined by the analysis of Condition Monitoring records. Refer to *ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring*, Section 8.

Note Not applicable where a single thruster, or podded propulsor, is solely responsible for the propulsion and/or steering of the vessel.

■ *Section 11* **Engines – Detailed requirements**

11.1 Complete Surveys

11.1.1 The requirements of *Pt 1, Ch 3, 10.3 Complete Survey of machinery* are to be complied with as far as is applicable.

11.1.2 The following parts are to be opened out and examined, but *see also Pt 1, Ch 3, 10.3 Complete Survey of machinery 10.3.10*:

Cylinders, covers, valves and valve gear, pistons, piston rods, crossheads, guides, connecting rods, crankshafts and all bearings, bedplates, crankcase door fastenings and explosion relief devices, scavenge blowers, superchargers and their associated coolers, air compressors and their intercoolers, filters and/or separators and safety devices, fuel pumps and fittings, camshaft drives, torsional vibration dampers or detuners, flexible couplings, clutches, reverse gears, attached pumps and cooling arrangements.

11.1.3 Selected pipes in the starting air system are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

11.1.4 The electric starting system, if fitted, is to be examined and tested.

11.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

■ *Section 12* **Electrical equipment**

12.1 Complete Surveys

12.1.1 A test for insulation resistance is to be made on the cables, switchgear, generators, motors, heaters, lighting fittings, etc. and the insulation resistance is to be not less than 100 000Ω between all insulated circuits and earth. The installation may be subdivided to any desired extent by opening switches, removing fuses or disconnecting appliances for the purpose of this test. The readings of the insulation resistance test are to be recorded.

12.1.2 The fittings on main and emergency switchboards, section boards and sub-distribution fuse boards are to be examined and overcurrent protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

12.1.3 Generator, switchgear and associated equipment are to be tested, so far as practicable, to verify that protective devices operate satisfactorily.

12.1.4 The electric cables are to be examined, so far as is practical, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by *Pt 1, Ch 3, 12.1 Complete Surveys 12.1.1*. Tests are to be carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

12.1.5 The generator prime movers are to be surveyed as required by *Pt 1, Ch 3, 11 Engines – Detailed requirements* and the governing of the engine tested. The motors concerned with essential services together with associated control and switchgear are to be examined and if considered necessary, are to be operated, so far as practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

12.1.6 Navigation light systems including indicators and associated alarms if fitted, are to be examined and tested.

12.1.7 In passenger ships, the emergency source of power and its associated circuits and where fitted, the temporary source of power and its automatic arrangements are to be tested.

12.1.8 If on cargo ships an emergency source of power has been fitted, this system and its associated circuits are to be tested.

12.1.9 Electrical equipment such as cables and certified safe type of equipment fitted in dangerous zones and spaces on tankers intended for the carriage of flammable gases and/or liquids is to be examined. Tests are to be carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

12.1.10 Battery compartments, lockers and boxes together with their ventilation compartments are to be examined.

12.2 Annual and Intermediate Surveys

12.2.1 In ships which are subjected to Annual Surveys as set out in *Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.2* the electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions, so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled, they should be tested in the automatic mode.

12.2.2 For special requirements for tankers, *see Pt 1, Ch 3, 2.2 Examination and testing for ships which are to be subjected to Annual Surveys as set out in Ch 2,3.5.1 2.2.2* and/or *Pt 1, Ch 3, 3.2 Examination and testing 3.2.12*.

■ *Section 13*
Boilers

13.1 Frequency of surveys

13.1.1 All boilers, thermal oil and hot water units intended for essential services, together with boilers used exclusively for non-essential services having a working pressure exceeding 3,5 bar and a heating surface exceeding 4,5 m^2 are to be surveyed internally. There is to be a minimum of two internal examinations during each five-year Special Survey cycle. The interval between any two such examinations is not to exceed 36 months. A general external examination is to be carried out at the time of the Annual Survey on ships subjected to Annual Survey.

13.1.2 Consideration may be given in exceptional circumstances to an extension of the internal examination of the boiler not exceeding three months beyond the due date. The extension may be granted after the following is satisfactorily carried out:

(a) External examination of the boiler.
(b) Examination and operational test of the boiler safety valve relieving gear (easing gear).
(c) Operational tests of the boiler protective devices.
(d) Review of the following records since the previous boiler survey:

- Operation
- Maintenance
- Repair history
- Feedwater chemistry.

Note : In this context 'exceptional circumstances' means unavailability of repair facilities, essential materials, equipment or spare parts.

13.2 Scope of surveys

13.2.1 At the surveys described in *Pt 1, Ch 3, 13.1 Frequency of surveys* the boilers are to be examined internally and externally and where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thickness of plates and tubes and sizes of stays are to be ascertained to determine a safe working pressure. The principal mountings on boilers are to be opened up and examined, and the safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable provided that the valves lift at not more than 103 per cent of the approved design pressure. The remaining mountings are to be examined externally and, if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

13.2.2 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

13.2.3 The fuel oil burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, control gear and oil discharge pipes between pumps and burners.

■ *Section 14*
Steam pipes

14.1 Frequency of surveys

14.1.1 Steam pipes are to be surveyed 10 years after the date of build and subsequently at every Special Survey.

14.2 Scope of surveys

14.2.1 At each survey, a selected number of steam pipes over 76 mm external diameter and with bolted joints, are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as practicable, the pipes are to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipeline will be tested.

14.2.2 Where these steam pipes have welded joints between lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, the welds examined, and, if considered necessary by the Surveyor, crack-detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

14.2.3 At Steam Pipe Surveys specified in *Pt 1, Ch 3, 14.1 Frequency of surveys 14.1.1*, any copper or copper alloy pipes, such as those having expansion or other bends, which may be subjected to bending and/or vibration, are to be annealed before being tested.

■ *Section 15*
Screwshafts, tube shafts and propellers

15.1 Frequency of surveys

15.1.1 All screwshafts are to be surveyed at intervals of five years.

15.1.2 When directional propellers for main propulsion purposes are fitted, they are to be opened up for examination of the working parts and control gear at intervals of five years.

15.2 Scope of surveys

15.2.1 All screwshafts and tube shafts are to be withdrawn for examination by LR’s Surveyors.

15.2.2 Controllable pitch propellers are to be surveyed at the same time as the screwshafts. The working parts and control gear are to be opened up for examination.

Section 16
Inert gas systems

16.1 Frequency of surveys

16.1.1 The whole inert gas installation is to be surveyed at intervals of 2½ years. For all ships having a Service extension notation, the survey is to be carried out concurrently with the examination in dry dock or on the slipway, *see Pt 1, Ch 2, 3.5 Existing ships – Periodical Surveys 3.5.7*, and at the Special Survey. For all other ships, the survey is to be carried out at every Intermediate and Special Survey.

16.2 Scope of surveys

16.2.1 The inert gas system, including alarms and safety devices, is to be examined and tested to demonstrate that it is in good working condition, to the satisfaction of the Surveyors.

Section 17
Classification of ships not built under survey

17.1 General

17.1.1 When classification is desired for a ship not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

17.1.2 Periodical Surveys of such ships, when classed, are subsequently to be held as in the case of ships built under survey.

17.2 Hull and equipment

17.2.1 Plans showing the main scantlings and arrangements of the actual ship, together with any proposed alterations, are to be submitted for approval. These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the ship.

17.2.2 In all cases, the full requirements of *Pt 1, Ch 3, 4 Special Survey – Hull requirements* are to be carried out. Ships over 15 years old are, in addition, to comply with the requirements of *Pt 1, Ch 3, 5 Special Survey of ships over 15 years old – Hull requirements*. In the case of tankers the requirements of *Pt 1, Ch 3, 6 Special Survey of tankers – Hull requirements*, *Pt 1, Ch 3, 7 Special Survey of tankers with cargo tanks independent from the ship's structure – Hull requirements* or *Pt 1, Ch 3, 8 Ships for liquefied gases under pressure and/or partially refrigerated* are also to be carried out.

17.2.3 During the survey, the Surveyors are to satisfy themselves regarding the materials, the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be gauged as necessary. Particulars of the anchors, chain cables and equipment are to be submitted. Fire protection, detection and extinction are to be in accordance with the Rules, *see Pt 6, Ch 3 Fire Protection, Detection and Extinction*. Ships of recent construction will receive special consideration.

17.3 Machinery

17.3.1 To facilitate the survey, plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings, are to be furnished with:

- General pumping arrangements, including air and sounding pipes.
- Pumping arrangements at the forward and after ends of ships carrying liquefied gases or liquids in bulk and drainage of cofferdams and pump-rooms.
- General arrangement of cargo piping in tanks and on deck of ships carrying liquefied gases or liquids in bulk.
- Vapourlines of cargo tanks, with information of type, capacity and set pressures of the pressure/vacuum valves, should be submitted for consideration for tankers of Type I, II, IIA, III and IIIA.

- Ventilation arrangement of cargo and/or ballast pump-rooms and other enclosed spaces which contain cargo handling equipment.
- Bilge, ballast and fuel oil pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.
- Arrangement of fuel oil pipes.
- Arrangement of fuel oil piping in connection with oil burning installations.
- Arrangement drawings of fuel oil service and other tanks not forming part of the ship's structure, fittings on settling and service tanks and their heating coils need not be submitted, provided the construction is to the Surveyor's satisfaction.
- Arrangement of compressed air systems and cooling water systems for main and auxiliary essential services.
- Fuel oil and cargo oil overflow systems, where these are fitted.
- Boiler feed systems and streamlines.
- Boilers which operate at a pressure greater than 3,4 bar (3,5 kgf/mm^2).
- Air receivers.
- Line of shafting.
- Steering gear.
- Where the ship has been in service for a length of time greater than five years, plans of clutch and reversing gear and reduction gearing need not be submitted provided they are of a type of design accepted by LR or manufactured to a recognized National or International Standard.
- Plans of the propeller (including spare propeller, if supplied) need not be submitted provided the propeller has been manufactured in a manner acceptable to LR.
- Electrical circuits.

17.3.2 Plans additional to those detailed in *Pt 1, Ch 3, 17.3 Machinery 17.3.1* are not to be submitted unless the machinery is of a novel or special character affecting classification.

17.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

17.3.4 For new ships and ships which have been in service less than five years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older ships, the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

17.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

17.3.6 The screwshaft is to be drawn and examined.

17.3.7 The steam pipes are to be examined and tested as required by *Pt 1, Ch 3, 14 Steam pipes*.

17.3.8 The bilge, ballast and fuel oil pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

17.3.9 Oil burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

17.3.10 The electrical equipment is to be examined as required at Complete Surveys.

17.3.11 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

17.3.12 Where classification is desired for a ship which is classed by another recognized Society, special consideration will be given to the scope of the survey.

Contents

Section 1
Rules for the Manufacture Testing and Certification of Materials

1.1 Reference

Please see *Rules for the Manufacture, Testing and Certification of Materials, July 2022*

Contents

Section

■ *Section 1* Rule application

1.1 General

1.1.1 The Rules apply in general to ships of normal form, proportions and speed. Relevant parameters to define what is regarded as normal are given by limitations specified at the beginning of individual ship type Chapters. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in hull construction will be considered.

1.2 Exceptions

1.2.1 Ships of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special service, not covered by *Pt 3 Ship Structures (General)* and *Pt 4 Ship Structures (Ship Types)*, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that ships will be properly loaded, discharged and handled; they do not, unless it is stated or implied in the class notations, provide for special distributions or concentrations of cargo or handling (loading and discharging sequences). Additional strengthening may be required to be fitted in any ship which will be subjected to severe stresses due to particular features of the design, exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability, trim, vibration, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 2* Additional calculations

2.1 General

2.1.1 Where approval is required for ships defined under *Pt 3, Ch 1, 1.2 Exceptions*, involving novel features of hull design or designs outside the limitations of these Rules, Lloyd's Register (hereinafter referred to as LR) may require additional calculations or model testing to be carried out. In such cases, LR is willing to undertake calculations for designers and/or make recommendations for model tests as required.

2.2 ShipRight direct calculation procedures

2.2.1 LR has direct calculation procedures and facilities available within the framework of the ShipRight procedures for the design, construction and lifetime care of ships.

■ *Section 3* Equivalents

3.1 Alternative arrangements

3.1.1 Alternative arrangements or fittings which are considered to be equivalent to those specified in the Rules will be accepted.

3.2 Alternative scantlings

3.2.1 In addition to cases where direct calculations are specifically required by the Rules for scantling assessment or confirmation purposes, LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule formulae. Where calculation procedures other than those available within ShipRight are employed, the assumptions made and the calculation procedure used are to be submitted for appraisal. The calculations are to be submitted for approval.

■ *Section 4* National and International Regulations

4.1 International Regulations

4.1.1 Attention is drawn to the necessity to comply with National and International Technical and Operational Regulations applicable where the ship is registered or operating and which may also contain requirements which are outside classification as defined in these Rules, e.g.

- European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN).
- The Regulations concerning the European Agreement on the International carriage of dangerous goods by inland waterways (ADN).

4.1.2 The exemptions and derogations to the regulations mentioned in *Pt 3, Ch 1, 4.1 International Regulations 4.1.1*, as authorised by the relevant authorities, may also be taken into consideration.

4.1.3 The Committee, when authorised, will act on behalf of Governments in respect of National and International statutory safety and other requirements for passenger and cargo ships.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

■ *Section 5* Information required

5.1 General

5.1.1 The categories and lists of information required are given in *Pt 3, Ch 1, 5.2 Plans*.

5.1.2 Plans are generally to be submitted in quadruplicate but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to define the structure fully, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual ship types are given in subsequent Chapters.

5.2 Plans

5.2.1 Plans suitably detailed covering the following items so far as applicable are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deck-houses and superstructures.
- Sternframe.
- Rudders, stocks, and tillers.
- Cargo tanks, independent of the ship’s structure.
- Support structure for cargo tanks independent of the ship’s structure.
- Equipment.
- Ice strengthening.
- Welding.
- Support structure for masts, derrick posts or cranes.
- Loading manual.
- Elevating wheelhouse systems

5.2.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan or equivalent information.
- Lines plan or equivalent.

5.2.3 The following supporting calculations are to be submitted:

- Calculation of equipment number, *see Pt 3, Ch 12 Ship Control Systems*.
- Calculation of hull girder still water bending moment and shear force as applicable, *see Pt 3, Ch 4 Longitudinal Strength*.
- Calculation of midship section modulus, *see Pt 3, Ch 3 Structural Design*.
- Calculations for structural items in the aft end, midship and fore end regions of the ship.

5.2.4 In cases where approval involves the use of computers, LR may require certain information to be given in a fixed format.

5.3 Plans to be supplied to the ship

5.3.1 To facilitate repairs and ordering of materials for that purpose it is recommended that plans be carried in the ship as indicated in *Pt 3, Ch 1, 5.2 Plans 5.2.1* so far as applicable. In case hull structural material other than Grade ‘A’ steel is incorporated in the ship, the disposition of this material and grades should be indicated on the plans with details of specification and mechanical and/or chemical properties, with recommendations for welding, working and treatment as may be necessary.

5.4 Fire protection, detection and extinction

5.4.1 For information and plans required, *see Pt 6, Ch 1 Control Engineering Systems*.

Section 6
Definitions

6.1 Principal particulars

6.1.1 Rule length, L, is the distance, in metres, on the deepest load waterline from the forward side of the stem or rake plating to the after side of the aftermost rudder post, or to the centre of the aftermost rudder stock if there is no rudder post. L is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the deepest load waterline. In ships with unusual stern arrangements the Rule length, L, will be specially considered.

6.1.2 Amidships is to be taken as the middle of the Rule length, L, measuring from the forward side of the stem or rake plating.

6.1.3 Breadth, B, is the greatest moulded breadth, in metres.

6.1.4 Depth, D, is measured at the middle of the length, L, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth, D, is to be measured to the continuation of the moulded deck line, in metres.

6.1.5 Draught, T, is the maximum draught, measured from top of keel, in metres.

6.1.6 The block coefficient, C_b, is the moulded block coefficient at draught, T, corresponding to deepest load waterline, based on Rule length, L, and moulded breadth, B, as follows:

$$C_{\mathrm{b}} = \frac{moulded displacement\left(\mathrm{m}^3\right) at draught T}{LBT}$$

6.1.7 Length between perpendiculars, L_{pp}, is the distance, in metres, on the deepest load waterline from the fore side of the stem to the after side of the aftermost rudder post, or to the centre of the aftermost rudder stock if there is no rudder post. In ships with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the deepest load waterline with the fore side of the stem or rake plating. The after perpendicular, A.P., is the perpendicular at the intersection of the deepest load waterline with the after side of the rudder post. For ships without a rudder post, A.P. is the perpendicular at the intersection of the waterline with the centreline of the aftermost rudder stock.

6.2 Passenger ship

6.2.1 A passenger ship is a ship which carries more than 12 passengers.

6.3 Reference system

6.3.1 For hull reference purposes, the ship is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid – L_{pp}.

6.4 Co-ordinate system

6.4.1 Unless otherwise stated, the co-ordinate system is as shown in *Figure 1.6.1 Co-ordinate system*, i.e. a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

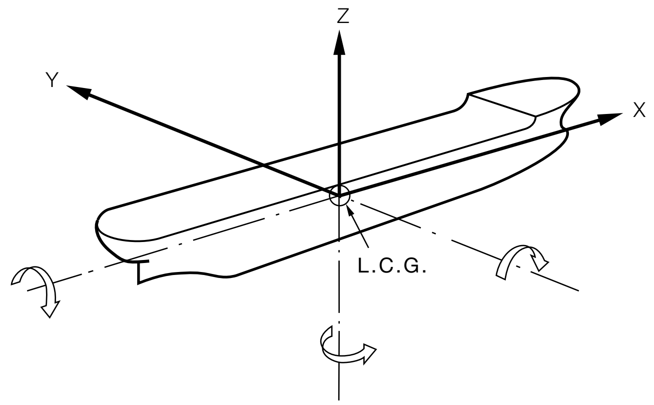


Figure 1.6.1 Co-ordinate system

Section 7
Inspection, workmanship and testing

7.1 Inspection

7.1.1 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection of all components during each stage of prefabrication and construction.

7.2 Workmanship

7.2.1 All workmanship is to be of good quality and in accordance with good shipbuilding practice. Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or other composition. The materials and welding are to be in accordance with the requirements of LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2022* (hereinafter referred to as the Rules for Materials). The assembly sequence and welding sequence are to be agreed prior to construction and are to be to the satisfaction of the Surveyor. Plates which have been subjected to excessive heating while being worked are to be satisfactorily heat treated before being erected in the hull.

7.2.2 **Wood sheathing on decks.** Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor.

7.2.3 **Rudder and sternframe.** The final boring out of the propeller boss and sternframe skeg or solepiece, and the fit-up and alignment of the rudder, pintles and axles is to be carried out after completing the major parts of the welding of the after part of the ship. Other methods will be specially considered. The contacts between conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

7.3 Acceptance testing on completion

7.3.1 **Hose testing.** The items listed in *Table 1.7.1 Hose testing requirements* are to be carefully examined and hose tested to the satisfaction of the Surveyor.

Table 1.7.1 Hose testing requirements

Item	Requirement
All ship types	
Watertight doors, in place	
Watertight bulkheads, flats and recesses	

Weathertight doors and other weathertight closing appliances Weathertight steel hatch covers Oil tankers and chemical tankers Pump-room bulkheads not forming tank boundaries Remainder of pump-room space, *see* Note	Pressure at least 0,2 N/mm^2 (2,0 kgf/cm^2) at maximum distance of 1,5 m from item under test, or equivalent
Note To be carefully examined with the vessel afloat and if found satisfactory the hose test may be dispensed with.	

7.3.2 **Pressure testing.** The items listed in *Table 1.7.2 Testing requirements* are to be subjected to the appropriate test head using water; however, a proposal for a combination of pressure testing and leak testing will be considered.

Table 1.7.2 Testing requirements

Item to be tested	Pressure testing requirements		Leak testing requirements - air pressure
All ship types, where appropriate			
Deep tanks, bunkers, peak tanks, side tanks, combined double bottom and side tanks, (including closing arrangements)	1 m head above the highest point of the tank, excluding hatchway, or to the top of the overflow, whichever is the greater, but is to be not less than 1,0ρ m above the top of the tanks where ρ is the relative density (specific gravity) of the intended cargo		0,007 N/mm^2 (0,07 kgf/cm^2)
Water ballast tanks	As for deep tanks		As for deep tanks
Cargo holds used for ballast	Depending on approved height of ballast in hold		As for deep tanks
Scupper and discharge pipes in way of tanks	As for deep tanks		As for deep tanks
Peak bulkheads not forming boundaries of tanks	Peaks to be filled with water to the level of the load waterline		-
Double plated rudders and nozzle	-		0,01 N/mm^2 (0,10 kgf/cm^2), and arrangements made to ensure that no pressure in excess of 0,015 N/mm^2 (0,15 kgf/cm^2) can be applied
Double bottom tanks	Head of water representing the maximum pressure which could be experienced in service, or to the top of the overflow, whichever is the greater		0,007 N/mm^2 (0,07 kgf/cm^2)
Watertight doors (passenger ships)	Each door is to be tested to a head up to the bulkhead deck, either before or after fitting		Not applicable
Void spaces (not accessible)	-		0,007 N/mm^2 (0,07 kgf/cm^2)
Tankers not carrying dangerous liquids in bulk			
Cargo tanks, cofferdams and cargo tanks not forming part of the ship's structure	1 m head of water above the highest point of the tank, excluding hatchway, or to top of hatchways for cofferdams, but is to be not less than 1,0ρ m above the top of the tank where ρ is the relative density (specific gravity) of the intended cargo		0,007 N/mm^2 (0,07 kgf/cm^2)
Item to be tested	Tanker type	Pressure testing requirements	Leak testing requirements – Air pressure
Tankers carrying dangerous liquids in bulk, *see Pt 4, Ch 6 Tankers of Types C and N*			

Cargo tanks and independent cargo tanks	G	Depending on properties of liquid	Not applicable
Cargo tank hatchways and covers	C and N Closed with design pressures from 10 up to and including 15 kPa	Tank to be subjected to a head of water of 0,13 x (design pressure in kPa) above top tank, excluding hatchways, *see* Note 1	0,007 N/mm2 (0,07 kgf/cm^2)
	C and N Closed with design pressures greater than 15 up to and including 50 kPa	Tank to be subjected to a head of water of 0,13 x (design pressure in kPa) above top tank, excluding hatchways	
	N Open with flame screens and N Open	1 m head of water above top of tank or 0,50 m above top of hatchway, whichever is greater	
Cofferdams with hatchways	G, C and N Closed, N Open with flame screens and N Open	1 m head of water above top of the cofferdam	0,007 N/mm2 (0,07 kgf/cm2)
Note 1. If the relative density (specific gravity) of the cargoes on which the scantlings of the tanks are based is in excess of 1, these test heads are to be multiplied by a factor equal to the relative density, but this factor should not be taken greater than 1,2.			
Note 2. The cargo tanks and cofferdams are to be tested using water.			
Note 3. In no case is the test pressure to be more than is indicated on the approved plans.			

7.3.3 **Leak testing.** This test is carried out by applying a soapy water solution to the tank boundaries while the tank is subjected to an air pressure of 0,007 N/mm^2 (0,07 kgf/cm^2). It is recommended that the air pressure in the tank is raised to 0,010 N/mm^2 (0,10 kgf/cm^2), with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure prior to inspection. Leak testing is normally to be carried out before a protective coating is applied. However, subject to careful inspection by the Surveyors, a complete protective coating may be applied prior to leak testing, except internally in way of welds made by processes other than automatic.

7.3.4 When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided that the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating, excluding prefabrication primers. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired. The attachment of fittings to oiltight surfaces should be completed before tanks are tested.

7.3.5 Pressure testing may be carried out afloat where testing using water is undesirable in dry dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head. For tankers, the testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in *Table 1.7.2 Testing requirements*. With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the bottom and lower side shell examined when the water is transferred to the remaining tanks. The sequence of tank testing is not to lead to unacceptable stresses being imposed upon the hull girder.

7.3.6 If, on cargo tanks of tankers, structural pressure testing has been carried out prior to the fitting of measuring devices, pipe connections and other equipment with passages through the deck or through the cargo hatch, additional leak tests are to be carried out in order to verify the tightness in way.

7.4 Trial trip and operational tests

7.4.1 The items listed in *Table 1.7.3 Trial trip and operational tests* are to be tested on completion of the installation or at sea trials.

Table 1.7.3 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.

Windlass	An anchoring test (bow and stern anchors) is to be carried out in the presence of the Surveyors. The test should demonstrate that the windlass with brakes, etc. functions satisfactorily and that the power to raise anchor can be developed.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors. Power operated steering gear is to be capable of moving the completely immersed rudder, whilst the ship is running ahead at maximum service speed, from 30° on either side to 30° on the other side within 15 seconds.
Bilge suctions in holds, and hand pumps in peak spaces	To be tested under working conditions to the satisfaction of the Surveyors.

Section

Section 1 Materials of construction

1.1 General

1.1.1 These Rules relate, in general, to the construction of steel ships, although consideration will be given to the use of other materials, when permitted by the Regulations of National and/or International Authorities for the type of ship.

1.1.2 The materials used in the construction of the ship are to be manufactured and tested in accordance with the requirements of Lloyd's Register's (hereinafter referred to as LR) *Rules for the Manufacture, Testing and Certification of Materials, July 2022*. Materials for which provision is not made in LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2022* may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

1.1.3 Where steel castings or forgings are used for sternframes, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2022*, *Pt 3, Ch 4 Longitudinal Strength* or *Pt 3, Ch 5 Fore End and Aft End Structure*, as appropriate.

1.1.4 Where aluminium alloy is used for superstructures, deckhouses, hatch covers or other structural components, equivalent scantlings are to be derived in accordance with *Pt 3, Ch 2, 1.4 Aluminium*.

1.2 Grades of steel

1.2.1 The ships covered by these Rules are generally to be constructed of Grade 'A' or 'AH' steel. In highly stressed areas, however, grades of steel with higher levels of notch toughness (Grades 'B', 'D', 'DH', 'E' or 'EH') may be required, dependent on the thickness of the material and the stress pattern associated with its location.

1.3 Steel

1.3.1 Steel having a specified minimum yield stress of 235 N/mm^2 is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

1.3.2 For the determination of the hull girder section modulus, where higher tensile steel is used, a higher tensile steel factor, k_L, is given in *Table 2.1.1 Values of K_L*.

Table 2.1.1 Values of K_L

Specified minimum yield stress in N/mm^2	k_L
235	1,0
265	0,92
315	0,78
355	0,72
Note 1. Intermediate values by linear interpolation.	

1.3.3 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a *k* factor determined as follows:

$$k = \frac{235}{\sigma_O}$$

or 0,66 whichever is the greater.

where

σ_O = specific minimum yield stress in N/mm^2

1.4 Aluminium

1.4.1 The use of aluminium alloy is permitted for superstructures, deckhouses, hatch covers, helicopter platforms or other local components on board ships.

1.4.2 Except where otherwise stated in Pt 3, Ch 8, 3 Aluminium erections, equivalent scantlings are to be derived as follows:

(a) Plating thickness,

$$t_a = t_s\sqrt{k_a c}$$

(b) Section modulus of stiffeners

$$Z_a = Z_s k_a c$$

where

c = 0,95 for high corrosion resistant alloy

= 1,00 for other alloys

k_a = $\frac{245}{\sigma_a}$

t_a = thickness of aluminium plating

t_s = thickness of mild steel plating

Z_a = section modulus of aluminium stiffener

Z_s = section modulus of mild steel stiffener

σ_a = 0,2 per cent proof stress or 70 per cent of the ultimate strength of the material, whichever is the lesser.

1.4.3 In general, for welded structures, the maximum value of sa to be used in the scantlings derivation is that of the aluminium in the welded condition. However, consideration will be given to using unwelded values depending upon the weld line location and other heat affected zones, in relation to the maximum applied stress on the member (e.g. extruded sections).

1.4.4 A comparison of the mechanical properties for selected welded and unwelded alloys is given in *Ch 13, 8.3 Fabrication and welding 8.3.2* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

■ *Section 2* Corrosion protection

2.1 General

2.1.1 All steelwork, except inside tanks intended for the carriage of oil or bitumen and inside void spaces which are permanently sealed, is to be suitably protected against corrosion. This may be by coating or by any other approved method. For the protection required in tanks carrying chemicals or other special cargoes, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*, *Pt 4, Ch 5 Tankers of Type G*, *Pt 4, Ch 6 Tankers of Types C and N*, and *Pt 4, Ch 7 Water Tankers, Wine Tankers and Edible Oil Tankers*.

2.1.2 Where bimetallic connections are made, measures are to be incorporated to preclude galvanic corrosion.

2.2 Surface preparation, prefabrication primers, and paints or coatings

2.2.1 Steelwork is to be suitably cleaned and cleared of millscale before the application of surface paints and coatings. It is recommended that blast cleaning or other equally effective means be employed for this purpose.

2.2.2 Where a primer is used to coat steel after surface preparation and prior to fabrication, and which is not type approved by LR for this purpose, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied.

2.2.3 To determine the influence of the primer coating on the characteristics of welds, tests are to be made to the Surveyors' satisfaction.

2.2.4 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Unless previously agreed, at least two coats are to be applied.

2.2.5 The paint or coating is to be compatible with any previously applied primer, *see Pt 3, Ch 2, 2.2 Surface preparation, prefabrication primers, and paints or coatings 2.2.2*.

2.2.6 Paints, varnishes and similar preparations having a nitrocellulose or other highly flammable base are not to be used in accommodation or machinery spaces.

2.2.7 In ships intended for the carriage of oil cargoes having a flash point below 55°C, paint containing aluminium should not, in general, be used in positions where cargo vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

■ *Section 3*
Deck covering

3.1 General

3.1.1 Where plated decks are sheathed with wood or an approved composition, reductions in plate thickness may be allowed.

3.1.2 The steel deck is to be coated with a suitable material in order to prevent corrosive action. Where sheathing or composition is used, it is to be effectively secured to the deck.

3.1.3 Deck coverings in the following positions are to be of a type which will not readily ignite when used on decks:

(a) forming the crown of machinery or cargo spaces within accommodation spaces of cargo ships;
(b) within accommodation spaces, control stations, stairways and corridors of passenger ships.

■ *Section 1* General

1.1 Application

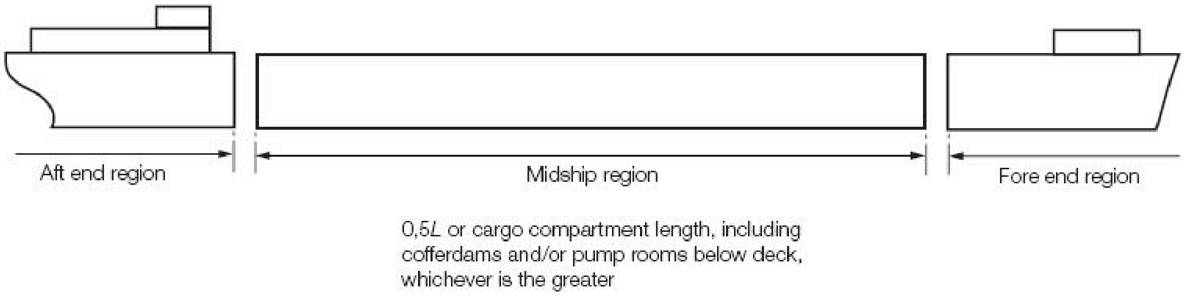
1.1.1 This Chapter illustrates the general principles to be adopted in applying the Rule structural requirements given in *Pt 3 Ship Structures (General)* and *Pt 4 Ship Structures (Ship Types)*. In particular, consideration has been given to the layout of the Rules as regards the different regions of the ship, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures.

1.1.2 Where additional requirements relating to particular ship types apply, these are, in general, dealt with under the relevant ship type Chapter in *Pt 4 Ship Structures (Ship Types)*.

■ *Section 2* Rule structural concepts

2.1 Definition of requirements

2.1.1 In *Figure 3.2.1 Breakdown of the ship into regions*, the breakdown of the ship into regions is shown. Within each region, the applicable Parts and Chapters of the Rules are indicated.



Sections covered	Part	Ch
Aft end structure	3	5
Rudders	3	12

Sections covered	Part	Ch
Hull scantlings	4	–
Longl. strength	3	4

Sections covered	Part	Ch
Fore end structure	3	5

Sections covered	Part	Chapter
Testing	3	1
Materials	3	2
Machinery spaces	3	6
Bulkheads	3	7
Superstructures	3	8
Special features	3	9
Welding and structural details	3	10
Closing arrangements, etc.	3	11
Ship control systems	3	12
Equipment	3	12

Figure 3.2.1 Breakdown of the ship into regions

2.2 Definition of midship region

2.2.1 The midship region structure is considered to include the structure within the greater of:

(a) the midship 0,5*L*, length,

(b) the cargo compartment length which on tankers includes the cofferdams and/or pump-rooms under deck.

2.3 Definition of fore end region

2.3.1 The fore end region structure is considered to include all structure forward of the midship region.

2.4 Definition of aft end region

2.4.1 The aft end region structure is considered to include all structure aft of the midship region.

2.5 Principles for taper

2.5.1 The thickness of the shell envelope and deck outside the line of openings between the 0,5*L* midship and 0,075*L* from the A.P. and 0,075*L* from the F.P., may be based on a direct taper from the midship thickness to the end thickness, as shown in *Figure 3.2.2 Principles for taper*, except where required otherwise in *Pt 4 Ship Structures (Ship Types)*.

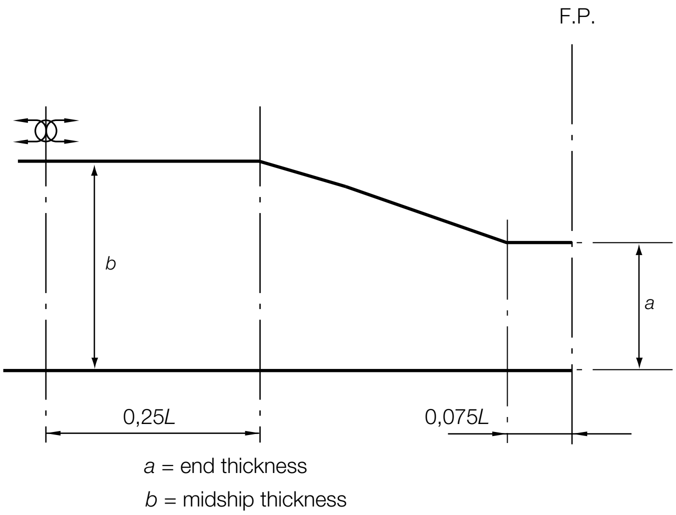


Figure 3.2.2 Principles for taper

2.6 Vertical extent of higher tensile steel

2.6.1 Higher tensile steel may be used for both deck and bottom structures or for deck structure only. Where fitted, it is to be used for the whole of the longitudinal continuous material for the following vertical distances:

(a) from the line of deck at side

$Z_{ht} = (1 - K_L)Z_P$

(b) from the top of keel

$Z_{ht} = (1 - K_L)Z_B$

where

k_L = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.2*

Z_D, Z_B = vertical distance, in metres, from the hull transverse neutral axis to the moulded deck line at side and to the top of keel respectively

Z_{ht} = vertical extent of higher tensile steel, in metres

2.7 Grouped stiffeners

2.7.1 Where stiffeners are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of the following:

(a) the mean value of the section modulus required for individual stiffeners within the group;
(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

2.8 Principles for rounding off

2.8.1 The thickness of hull structural components calculated by using the formulæ for these components should be rounded off for so far as they deviate from full or half millimetres according to *Table 3.2.1 Principles for rounding off*.

Table 3.2.1 Principles for rounding off

Thickness in excess of whole number by		Rounded to
Over	Not exceeding	

-	0,25 mm	0
0,25 mm	0,75 mm	0,5 mm
0,75 mm	1,0 mm	1,0 mm

2.9 Frame spacing

2.9.1 The frame spacing of transverse or longitudinal frames is generally to be within the range given by the following formula:

$$S = (340 + 23\sqrt{L - 10}) \pm 70\text{mm}$$

Proposals for frame spacings different from this range will be specially considered.

■ *Section 3* Structural idealisation

3.1 General

3.1.1 For derivation of scantlings of stiffeners, beams, girders, etc. the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

3.1.2 The properties of stiffener, beam or girder are defined by a section modulus and a moment of inertia. Apart from local requirements for web thickness, the minimum thickness in relation to the plating to which it is connected is to comply with *Table 3.3.1 Minimum web plating thickness in relation to the connected plating*. Primary members are also to comply with the requirements of *Pt 3, Ch 10, 4 Construction details for primary members*.

Table 3.3.1 Minimum web plating thickness in relation to the connected plating

Plating thickness	Web thickness
3,5 - 5 mm	4 mm
6 - 7 mm	5 mm
8 - 9 mm	6 mm
above 9 mm	7 mm

3.1.3 For flat bar stiffeners, the ratio of depth to thickness should not exceed 16.

3.2 Geometric properties of section

3.2.1 The symbols used in this sub-Section are defined as follows:

l = the overall length, in metres, of the support member, *see Pt 3, Ch 3, 3.2 Geometric properties of section 3.2.1*

b = the actual width, in metres, of the load-bearing plating, i.e. one half of the sum of spacings between parallel adjacent members or equivalent supports, *see Pt 3, Ch 3, 3.2 Geometric properties of section 3.2.1*

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used

f = $0,3\left(\frac{l}{b}\right)^{\frac{2}{3}}$ but is not to exceed 1,0.

Values of this factor are given in *Table 3.3.2 Values of f as a function of l/b* .

Table 3.3.2 Values of *f* as a function of l/b

$\frac{l}{b}$	f	$\frac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6 and above	1,00
Note Intermediate values to be obtained by linear interpolation.			

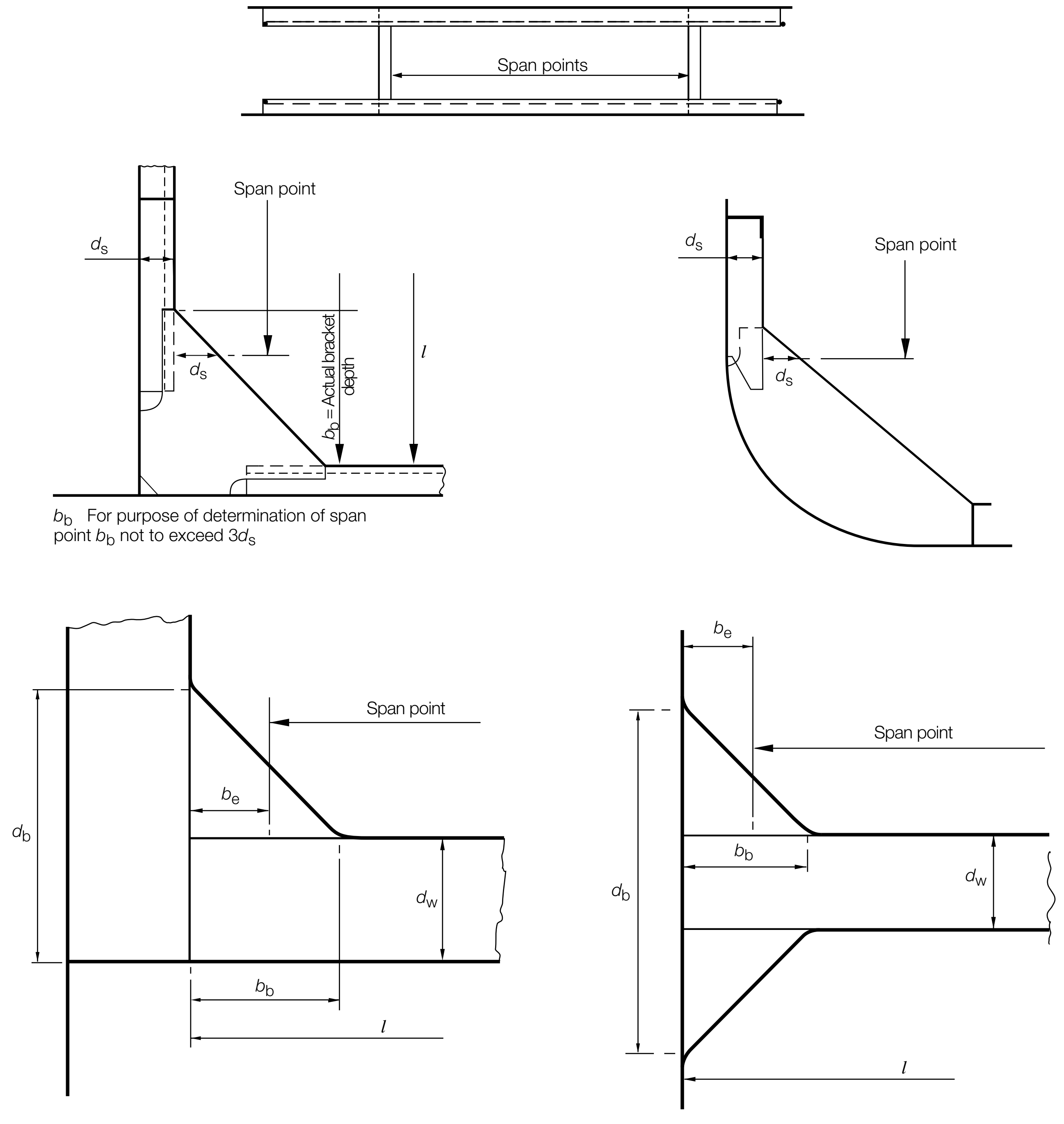


Figure 3.3.1 Determination of span points

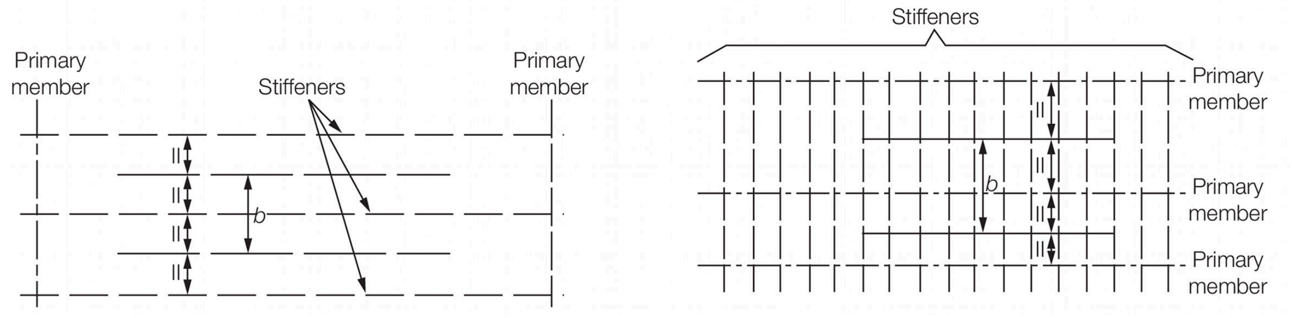


Figure 3.3.2 Determination of load-bearing plating

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Alternatively, the geometric properties may be taken from *Pt 3, Ch 3, 5 Geometric properties of rolled sections*. Where the web of the section is not normal to the attached plating, the angle is not normal to the attached plating, and exceeds 20, the properties of the section are to be determined about an axis parallel to the attached plating, alternatively, the required section modulus is to be multiplied by a factor:

$$= 1 + 0,01\left(\frac{90 - \alpha}{7}\right)^2$$

where

α is the angle between stiffener and plating.

3.2.3 The geometric properties of rolled or built stiffener sections are to be calculated in association with an effective area of attached load-bearing plating of thickness t_p in mm and of width 500 mm; for swedges, the width of plating is to be taken as the actual width of flat plating between the swedges. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing, *s*, is to be calculated from the dimensions, and for symmetrical corrugations, may be taken as:

$$Z = \frac{d_w}{6000}\left(3bt_p + ct_w\right) \text{ cm}^3$$

where d_w, b, t_p, c and t_w are measured, in mm, and are as shown in *Figure 3.3.3 Dimensions and symbols for corrugated bulkheads*. The value of *b* is to be taken not greater than $50t_p$ in this calculation, and θ is to be not less than 40°. The moment of inertia is to be calculated from:

$$I = \frac{Z}{10}\left(\frac{d_w}{2} + t_p\right) \text{cm}^4$$

3.2.5 For symmetrical corrugations the following additional requirements are also to be complied with:

(a) the ratio b/t_p should not exceed $70\sqrt{k}$
(b) the ratio c/t_p should not exceed $85\sqrt{k}$

k = see Pt 3, Ch 2, 1.3 Steel 1.3.3

(c) d_w is to be not less than $39l_e$ mm (for deep tank bulkheads only),
(d) the plating thickness at the middle of span l_e of corrugated bulkheads is to extend not less than $0,2l_e$ above mid span, (for definition of l_e, *see Pt 3, Ch 3, 3.3 Determination of span point*).

3.2.6 The effective section modulus of a built section may be taken as:

$$Z = \frac{ad_w}{10} + \frac{t_w d_w^2}{6000}\left(1 + \frac{200(A - a)}{200A + t_w d_w}\right)\text{cm}^3$$

where

a = the area of the face plate of the member, in cm^2

A = the area, in cm^3, of the attached plating, *see Pt 3, Ch 3, 3.2 Geometric properties of section 3.2.7*. If the calculated value of A is less than the face area a, then A is to be taken as equal to a

d_w = the depth of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken in, mm

t_w = the thickness of the web of the section, in mm.

Rolled or built sections fitted on top of supported stiffening members, *see Figure 3.3.4 Rolled or built sections fitted on top of supported stiffening members*, are to have a modulus not less than two thirds of the modulus required for the primary member in the same position. This section should be attached at both ends of the plating for at least one stiffener spacing and should also be properly attached to the supported stiffeners.

3.2.7 The geometric properties of primary support members, i.e. girders, transverses, webs, stringers, etc. are to be calculated in association with an effective area of attached load-bearing plating, A, determined as follows:

(a) For a member attached to plane plating:

$A = 10fbt_p$ cm^2 (for f, *see Table 3.3.2 Values of f as a function of l/b*)

(b) For a member attached to corrugated plating and parallel to the corrugations:

$A = 10bt_p$ cm^2

See Figure 3.3.3 Dimensions and symbols for corrugated bulkheads

(c) For a member attached to corrugated plating and at right angles to the corrugations:

A is to be taken as equivalent to the area of the face plate of the member.

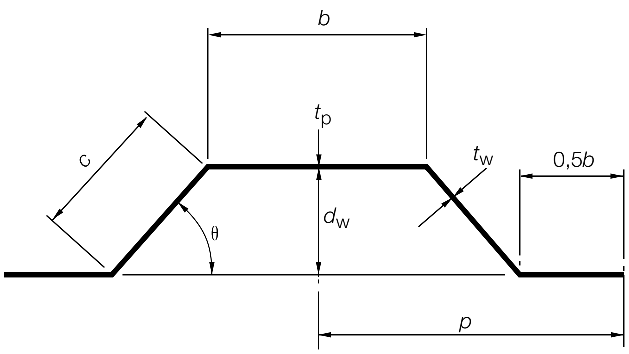


Figure 3.3.3 Dimensions and symbols for corrugated bulkheads

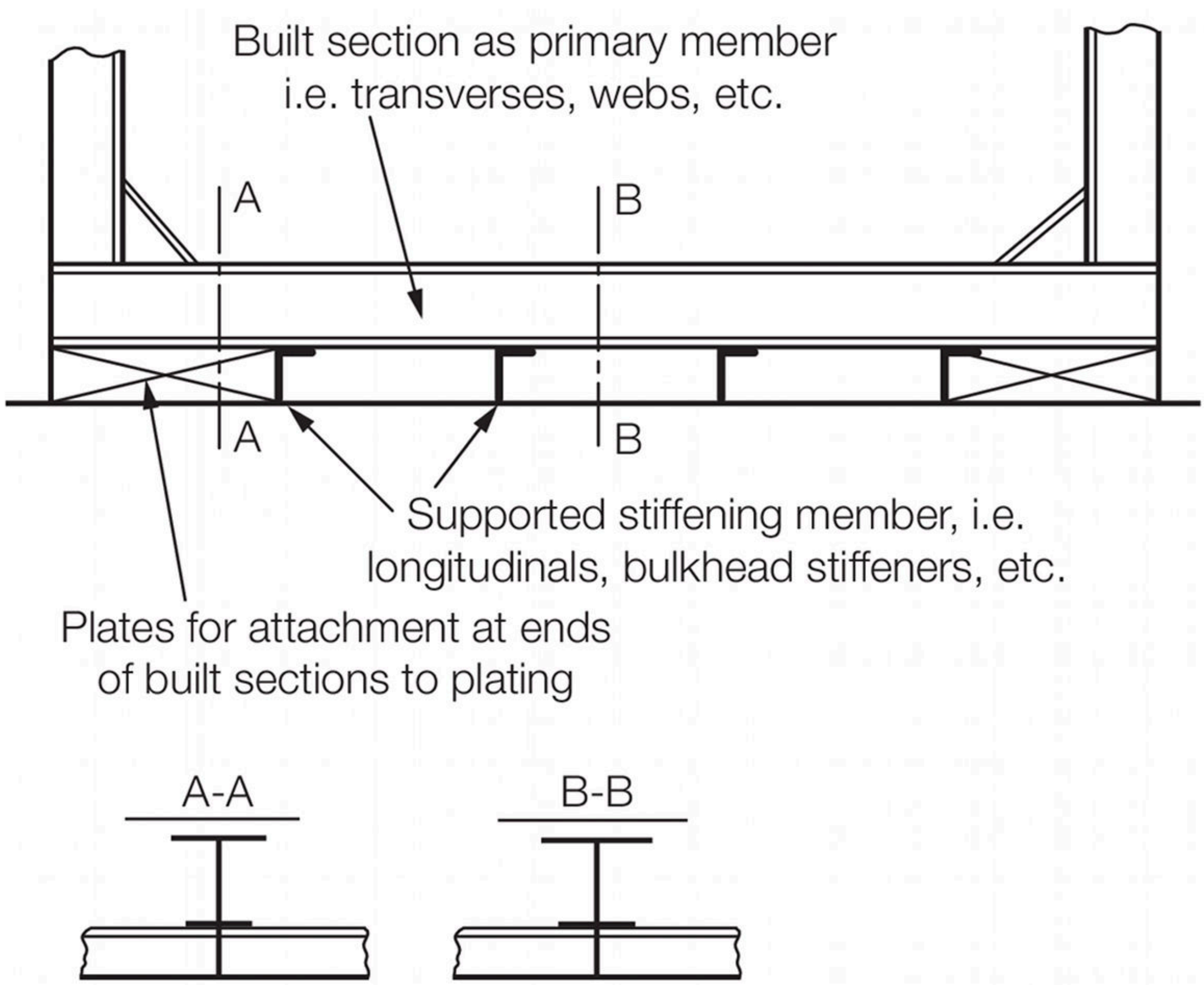


Figure 3.3.4 Rolled or built sections fitted on top of supported stiffening members

3.3 Determination of span point

3.3.1 The effective span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built stiffener sections, swedges and corrugations:

The span point is to be taken at the point where the depth of the end bracket, measured from the face of the stiffener is equal to the depth of the stiffener. Where there is no Rule end bracket, the span point is to be taken at the end of the stiffener.

(b) For primary support members, i.e. girders, transverses, webs, stringers, etc.:

The span point is to be taken at a point distant b_e from the end of the member,

where:

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

See also Pt 3, Ch 3, 3.2 Geometric properties of section 3.2.1.

3.3.2 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

3.4 Calculation of hull section modulus

3.4.1 All continuous longitudinal structural material is to be included in the calculation of the inertia of the hull midship section, and the lever z is, except where otherwise specified for particular ship types, to be measured vertically from the neutral axis to the top of keel and to the moulded strength deck line at the side. The strength deck is to be taken as follows:

(a) Where there is a complete upper deck and no effective superstructure, the strength deck is the upper deck.

(b) Where there is an effective superstructure or a stepped deck the position of the strength deck will be specially considered.

3.4.2 An effective superstructure is a superstructure extending over the full breadth of the ship and which exceeds 0,20*L* in length or 10 m whichever is the greater and is situated within the 0,5*L* region.

3.4.3 Lightening holes in girders need not be deducted, provided that their depth does not exceed 20 per cent of the web depth.

3.4.4 Isolated weld scallops, drain and air holes in longitudinals need not be deducted, provided that their depth does not exceed 65 mm. In no case is the opening to be greater than 25 per cent of the web depth. Such openings are considered isolated if they are spaced not less than 1 m apart.

3.4.5 In general, isolated deck openings need not be deducted, but compensation may be required. *See* individual ship type Chapters.

3.4.6 Where trunk decks or continuous hatch coamings are effectively supported by longitudinal bulkheads or deep girders, they are to be included in the longitudinal sectional area when calculating the hull section modulus. The lever z_t is to be taken as:

$z = z_c\left(0,9 + 0,2\frac{y}{b}\right)$ m but not less than z

where

y = horizontal distance from top of continuous strength member to the centreline of the ship, in metres

z = vertical distance from the newtral axis to the moulded deck line at side, in metres

z_c = vertical distance from the neutral axis to the top of the continuous strength member, in metres

z_c and y are to be measured to the point giving the largest value of z_t

■ *Section 4* Design loading

4.1 General

4.1.1 This Section contains the design heads/pressures to be used in the derivation of scantlings for decks, tank tops and transverse bulkheads. Where scantlings in excess of Rule requirements are fitted, the procedure to be adopted to determine the permissible loading pressure which may be carried by such scantlings is given in *Table 3.4.1 Design heads and permissible cargo loading (SI units)*.

Table 3.4.1 Design heads and permissible cargo loading (SI units)

	Rule Loading				
Structural item and position	Component	Stowage rate, in m^3/tonne	Design loading p, in kN/m^2	Design head h_i, in metres	Permissible cargo loading, in kN/m^2
Upper deck outside of accommodation spaces				h_1	
Loading for minimum scantlings	All structure	1,39	4,59	0,65	4,59
Cargo decks, tank top or hold ceiling				h_2	
General cargo (standard loads)	All structure	1,39	$7{,}07H_c$	H_c	$7{,}07H_c$
Machinery space, workshop and stores		1,39	18,37	2,6	18,37
Ship stores		1,39	9,22	1,3	9,22
Accommodation decks	All structure	1,39	3,18	$h_3 = 0{,}45$	3,18
Watertight bulkheads	Plating and stiffeners	1	h_4	h_4 from *Figure 3.4.2 Heads for watertight and deep tank bulkheads*	
Deep tank bulkheads					
Hatch covers (standard loading) *see* Note	All structure	1,39	1,47	$h_H = 0{,}21$	1,47
	Applied loading				
Upper deck outside of accommodation spaces				h_1	
Specified cargo loading	All structure	C	p_a	$\frac{Cp_a}{9,82}$	p_a
Cargo decks, tank top or hold ceiling				h_2	
Special cargo (specified loads)	All structure	C	p_a	$\frac{Cp_a}{9,82}$	p_a
Deep tank bulkheads	Plating and stiffeners	C but ≤ 1	$\frac{h_4}{C}$	h_4 from *Figure 3.4.2 Heads for watertight and deep tank bulkheads*	
Hatch covers (specified loading)	All structure	C	p_a	$h_H = \frac{Cp_a}{9,82}$	p_a

Note For ships operating in Zone 3 only, hatch covers may be designed for a minimum design loading of 0,075 tonne-f/m^2 plus the selfweight of the covers.

Table 3.4.2 Design heads and permissible cargo loading (metric units)

	Rule Loading				
Structural item and position	Component	Stowage rate, in m^3/tonne	Design loading p, in kN/m^2	Design head h_i, in metres	Permissible cargo loading, in kN/m^2
Upper deck outside of accommodation spaces				h_1	
Loading for minimum scantlings	All structure	1,39	0,468	0,65	0,468
Cargo decks, tank top or hold ceiling				h_2	
General cargo (standard loads)	All structure	1,39	$\frac{H_c}{1,39}$	h_c	$\frac{H_c}{1,39}$
Machinery space, workshop and stores		1,39	1,87	2,6	1,87
Ship stores		1,39	0,94	1,3	0,94
Accommodation decks	All structure	1,39	0,324	h_3 = 0,45	0,324
Watertight bulkheads	Plating and stiffeners	1	h_4	h_4 from *Figure 3.4.2 Heads for watertight and deep tank bulkheads*	
Deep tank bulkheads					
Hatch covers (standard loading) *see* Note	All structure	1,39	0,15	h_H = 0,21	0,15
	Applied loading				
Upper deck outside of accommodation spaces				h_1	
Specified cargo loading	All structure	C	p_a	Cp_a	p_a
Cargo decks, tank top or hold ceiling				h_2	
Special cargo (specified loads)	All structure	C	p_a	Cp_a	p_a
Deep tank bulkheads	Plating and stiffeners	C but ≤ 1	$\frac{h_4}{C}$	h_4 from *Figure 3.4.2 Heads for watertight and deep tank bulkheads*	
Hatch covers (specified loading)	All structure	C	p_a	$h_H = Cp_a$	p_a
Note For ships operating in Zone 3 only, hatch covers may be designed for a minimum design loading of 0,075 tonne-f/m^2 plus the selfweight of the covers.					

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

p = design loading which is either the Rule loading as defined in *Table 3.4.1 Design heads and permissible cargo loading (SI units)* or the applied loading p_a, whichever is the greater, in kN/m^2 (tonne-f/m^2)

p_a = applied loading, i.e. the actual loading specified by the builder or the Owner, in kN/m^2 (tonne-f/m^2)

h_i = design head, which is to be used in the Rule formulæ, in metres

= $p \times C$ where p has been defined in tonne-f/m^2, or

= $p \times C/9.81$ where p has been defined in kN/m^2

C = stowage rate, in m^3/tonne

= $\dfrac{\text{volume of hold, in m}^3}{\text{weight of cargo, in tonnes}}$ for inner bottom or hold ceiling

= $\dfrac{h_i}{p}$ elsewhere

l_e = span of stiffener, in metres

H_c = height from inner bottom, hold ceiling or cargo deck, to deck at side or underside of hatch covers or height of deck cargo, in metres, as defined in *Figure 3.4.1 Design heads for inner bottoms and & 'tweendecks*.

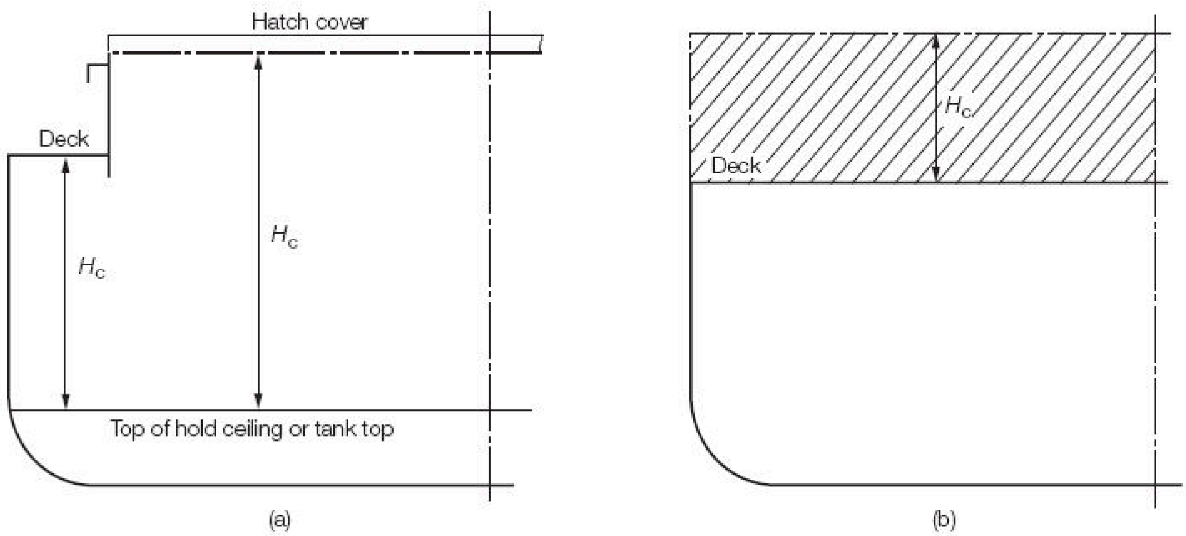
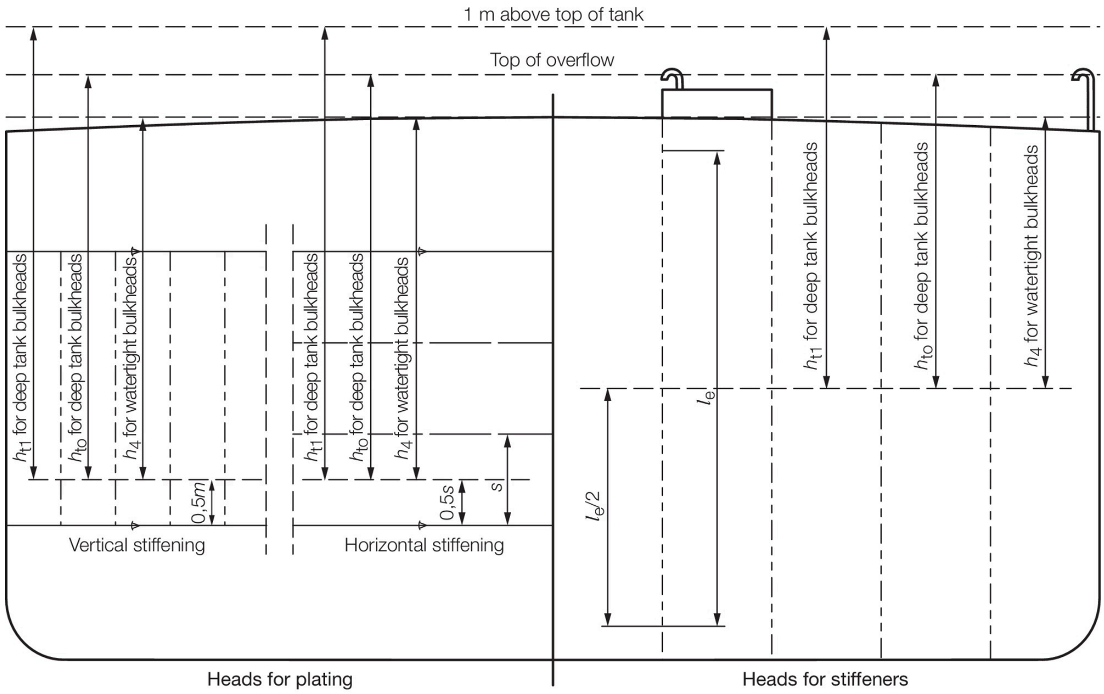


Figure 3.4.1 Design heads for inner bottoms and & 'tweendecks



h_4 = load head, in metres, measured vertically as follows:

(a) for vertically stiffened watertight bulkhead plating:
the distance from a point 0,5 m above the lower edge of the plate to the top of the bulkhead

(b) for horizontally stiffened watertight bulkhead plating:
the distance from the middle of the first panel above the lower edge of the plate to the top of the bulkhead

(c) for vertically stiffened deep tank bulkhead plating:
the distance from a point 0,5 m above the lower edge of the plate to a point 1 m above the top of the tank (h_{t1}), or to the top of the overflow (h_{to}), whichever is the greater

(d) for horizontally stiffened deep tank bulkhead plating:
the distance from the middle of the first panel above the lower edge of the plate to a point 1 m above the top of the tank (h_{t1}), or to the top of the overflow (h_{to}), whichever is the greater

(e) for watertight stiffeners or girders, the distance from the middle of the effective length to the top of the bulkhead

(f) for deep tank bulkhead stiffeners or girders, the distance from the middle of the effective length to a point 1 m above the top of the tank (h_{t1}), or to the top of the overflow (h_{to}), whichever is the greater

Figure 3.4.2 Heads for watertight and deep tank bulkheads

4.3 Stowage rate and design loads

4.3.1 Unless it is specifically requested otherwise, the following Rule standard stowage rates are to be used:

(a) 1,39 m^3/tonne for weather or general cargo loading on deck and inner bottom or hold ceiling.

(b) 1,0 m^3/tonne for liquid cargo of density of 1 tonne/m^3 or less on watertight and tank divisions. For liquid of density greater than 1 tonne/m^3 the corresponding stowage rates are to be adopted.

4.3.2 Proposals to use a stowage rate greater than 1,39 m^3/tonne for permanent structure will require special consideration, and will normally be accepted only in the case of special purpose designs.

4.3.3 The design head and permissible cargo loading are shown in *Table 3.4.1 Design heads and permissible cargo loading (SI units)*.

Section 5
Geometric properties of rolled sections

5.1 General

5.1.1 For convenience, geometric properties of rolled sections may be derived from *Table 3.5.1 Inverted angle bars*, *Table 3.5.2 Flat bars* and *Table 3.5.3 Holland profiles*. Alternatively, the effective geometric properties of rolled sections may be calculated directly from dimensions of the section and associated area of attached plating.

Table 3.5.1 Inverted angle bars

	Plating thickness 4 – 8 mm			Plating thickness 9 – 12 mm		
	A, in cm2 of section only	*I*, in cm^4	*Z*, in cm^3	*A*, in cm^2	*I*, in cm^4	*Z*, in cm^3
45 × 45 × 4	3,49	45	10			
45 × 45 × 6	5,09	59	14			
50 × 50 × 5	4,80	67	15			
60 × 40 × 5	4,79	92	16			
50 × 50 × 6	5,69	75	17			
50 × 50 × 8	7,41	90	21	7,41	118	24
60 × 40 × 7	6,55	115	22	6,55	142	24
60 × 60 × 6	6,91	128	25			
65 × 50 × 7	7,6	149	27	7,6	189	30
80 × 40 × 6	6,89	203	29			
60 × 65 × 6	7,53	161	30			
60 × 60 × 8	9,03	152	31	9,03	197	35
65 × 50 × 9	9,58	173	33	9,58	223	36
75 × 50 × 7	8,3	207	34	8,3	259	37
80 × 40 × 8	9,01	245	36	9,01	298	39
80 × 60 × 6	8,11	250	36			
65 × 65 × 8	9,85	191	37	9,85	247	41
70 × 70 × 7	9,4	218	39	9,4	279	43
75 × 50 × 9	10,5	240	40	10,5	308	44
100 × 50 × 6	8,73	364	45			
70 × 70 × 9	11,9	251	48	11,9	330	52
80 × 60 × 8	10,6	309	48	10,6	380	51
100 × 50 × 8	11,5	435	56	11,5	550	61
80 × 80 × 8	12,3	368	58	12,3	445	63
100 × 65 × 7	11,2	462	60	11,2	584	65

100 × 75 × 7	11,9	499	66	11,9	635	71
80 × 80 × 10	15,1	417	69	15,1	513	74
100 × 65 × 9	14,2	534	73	14,2	693	79
100 × 75 × 9	15,1	662	84	15,1	754	88
90 × 90 × 10	17,1	620	90	17,1	741	96
100 × 75 × 11	18,2	696	95	18,2	855	102
130 × 65 × 8	15,1	906	96	15,1	1160	103
90 × 90 × 12	20,3	683	103	20,3	828	110
130 × 75 × 8	15,9	1045	107	15,9	1250	113
100 × 100 × 10	19,2	777	111	19,2	964	118
130 × 65 × 10	18,6	1110	116	18,6	1343	124
100 × 100 × 12	22,7	850	126	22,7	1070	135
130 × 75 × 10	19,6	1266	129	19,6	1446	135
150 × 75 × 9	19,5	1545	142	19,5	1865	151
130 × 75 × 12	23,3	1405	148	23,3	1620	156
120 × 120 × 10	23,2	1371	164	23,2	1656	173
150 × 75 × 11	23,6	1848	169	23,6	2194	179
150 × 90 × 10	23,2	1924	178	23,2	2210	186
120 × 120 × 12	27,5	1505	187	27,5	1841	199
150 × 100 × 10	24,2	1895	188	24,2	2340	200
150 × 90 × 12	27,5	2126	204	27,5	2464	214
150 × 100 × 12	28,7	2085	215	28,7	2607	230
130 × 130 × 12	30	1732	216	30	2207	232
180 × 90 × 10	26,2	2902	228	26,2	3336	239
130 × 130 × 14	34,7	1860	241	34,7	2398	260
180 × 90 × 12	31,2	3218	263	31,2	3732	276
200 × 100 × 10	29,2	3866	282	29,2	4460	295
150 × 150 × 12	34,8	2540	290	34,8	3259	310
200 × 100 × 12	34,8	4278	325	34,8	4977	341
150 × 150 × 15	43	3056	348	43	3659	367

Table 3.5.2 Flat bars

	Plating thickness 4 – 8 mm			Plating thickness 9 – 12 mm		
	A, in cm^2	*I*, in cm^4	*Z*, in cm^3	*A*, in cm^2	*I*, in cm^4	*Z*, in cm^3
50 × 5	2,5	23	5			
50 × 7	3,5	31	6	3,5	39	7

60 × 5	3	38	6			
65 × 5	3,25	47	7			
50 × 9	4,5	39	8	4,5	49	9
60 × 7	4,2	51	9	4,2	62	10
65 x 7	4,55	64	10	4,55	76	11
60 x 9	5,4	64	11	5,4	77	13
75 x 6	4,5	83	12			
65 x 9	5,85	79	13	5,85	95	15
75 x 8	6	106	16	6	125	17
75 x 10	7,5	135	19	7,5	152	21
90 x 7	6,3	164	19	6,3	182	21
90 x 9	8,1	203	25	8,1	227	26
100 x 8	8	245	27	8	272	28
90 x 11	9,9	250	30	9,9	269	32
110 x 8	8,8	319	32	8,8	353	34
100 x 10	10	308	34	10	330	35
110 x 10	12,1	383	39	12,1	428	42
100 x 12	12	358	40	12	385	41
110 x 12	13,2	443	46	13,2	498	49
130 x 9	11,7	555	49	11,7	617	51
130 x 11	14,3	680	60	14,3	729	62
130 x 13	16,9	806	71	16,9	835	72
150 x 10	15	930	72	15	996	74
150 x 12	18	1115	86	18	1154	88
150 x 14	21	1256	99	21	1302	101

Table 3.5.3 Holland profiles

	Plating thickness 4 – 8 mm			Plating thickness 9 – 12 mm		
	A, in cm2 of section only	*I*, in cm^4	*Z*, in cm^3	*A*, in cm^2	*I*, in cm^4	*Z*, in cm^3
80 x 5	5,4	158	21			
80 x 7	7	186	25	7	213	27
100 x 6	7,74	320	35			
100 x 8	9,74	367	42	9,74	420	44
120 x 6	9,31	534	51			
120 x 8	11,71	608	59	11,71	695	63
140 x 7	12,4	892	76	12,4	1016	80
140 x 9	15,2	999	87	15,2	1151	92
160 x 7	14,8	1357	104	14,8	1556	110
160 x 9	17,8	1491	117	17,8	1728	124
180 x 8	18,9	2064	148	18,9	2396	156
180 x 10	22,5	2246	165	22,5	2633	175
200 x 9	23,5	2968	200	23,5	3483	212
200 x 11	27,6	3196	220	27,6	3785	235
220 x 10	29	4169	268	29	4950	285
220 x 12	33,4	4387	287	33,4	5244	307
240 x 10	32,4	5371	325	32,4	6412	346
240 x 12	37,3	5724	354	37,3	6877	379
260 x 11	38,7	7097	415	38,7	8549	443
260 x 13	43,3	7421	439	43,3	8959	471

■ *Section 1* Application

1.1 General

1.1.1 The requirements of this Chapter apply to both self-propelled ships with machinery aft and to non-propelled ships (barges and pontoons).

1.1.2 For the determination of the longitudinal strength, design bending moments are to be calculated for all ships with a length, *L*, exceeding 65 m. The methods for calculation of design bending moments are given in *Pt 3, Ch 4, 5 Design bending moments*. The determination of longitudinal strength of ships with a length, *L*, of 65 m and less is generally not required.

1.1.3 The longitudinal strength of self-propelled ships where the machinery space is not situated aft and the length, *L*, exceeds 40 m will be specially considered; the design bending moments are to be determined by direct calculation.

■ *Section 2* General

2.1 Loading conditions for determination of design bending moments

2.1.1 The following conditions are to be covered by the calculations of design bending moments:

(a) Light condition (ship completely equipped, fresh water tanks, fuel tanks and lubricating oil tanks full, crew and stores on board and tanks partly filled or full with water ballast if intended to be carried in this condition).
(b) Fully loaded condition, ship as in light condition and loaded with cargo, as evenly distributed as is practicable in the cargo compartment space, to the maximum allowable draught on even keel.
(c) Any other loading condition of the ship giving higher values of bending moments or shear forces, caused by loading and discharging sequences and/or unusual or non-uniform cargo distribution, *see also Pt 1, Ch 2, 2.1 Definitions 2.1.8*, *Pt 1, Ch 2, 2.1 Definitions 2.1.9* and ship type Chapters.

2.1.2 For ships designed, modified and/or arranged for navigation in Zones 3, 2 or 1 or for service extension, the additional wave bending moment and wave shear force for the particular zone or service extension area are to be added to the still water bending moment and shear force calculated for the conditions (a), (b) and (c) of *Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments 2.1.1* to obtain the actual maximum bending moment and shear force for calculation of the required hull section modulus.

2.1.3 The maximum still water bending moment corresponding to the ship's longitudinal strength category, *see Pt 3, Ch 4, 2.3 Longitudinal strength categories*, may not be exceeded when the ship is partly loaded due to navigational or operational requirements.

2.1.4 The longitudinal strength will be specially considered for ships designed, modified and/or arranged for any unusual loading condition, uneven cargo distribution, etc.

2.2 Definition of loading sequences ‘T’, ‘O’ and ‘D’

2.2.1 Loading/discharging sequence ‘T’, for normal loading sequence.

Self-propelled ships with machinery aft:

Loading of the ship in two runs of practically equal mass, by distributing the cargo evenly over the full length of the cargo compartment space. The loading is to commence from the after end and to progress to the forward end and then be completed by loading from forward to aft. Discharging in two runs of practically equal mass, taking the cargo evenly from the full length of the cargo compartment space, progressing from the after end to forward and completing the discharging from forward to aft.

Non-propelled ships:

Loading and discharging in two runs of practically equal mass, by distributing the cargo evenly over the full length of the cargo compartment and discharging by taking the cargo evenly from the cargo compartment space. The loading may be carried out from forward to aft and be completed from aft to forward or in the opposite direction. Discharging may be carried out in the same manner as loading.

2.2.2 Loading/discharging sequence ‘O’ for accelerated loading sequence.

Self-propelled ships with machinery aft:

Loading in one run. Loading to commence from the after end of the cargo compartment space and to progress to the forward end with the total mass of cargo evenly distributed.

Discharging in one run. Discharging to commence from the forward end of the cargo compartment space and to progress to the aft end.

Non-propelled ships:

Loading in one run, which may be commenced either from the forward end or the after end and evenly distributing the total mass of cargo to complete the loading at the other end of the cargo compartment space.

Discharging in one run, which may be commenced either from the forward or the after end of the cargo compartment space.

2.2.3 Loading/discharging sequence ‘D’ for defined loading sequence.

2.3 Longitudinal strength categories

2.3.1 For the purpose of longitudinal strength (L.S.), the Rules distinguish between three ship categories, defined as follows:

Category ‘T’

Ships for which the required section modulus is based on the maximum bending moments and shear forces occurring when the ships are being loaded and/or discharged according to the loading sequence ‘T’, *see Pt 3, Ch 4, 2.2 Definition of loading sequences ‘T’, ‘O’ and ‘D’* and/or ship type Chapter.

Category ‘O’

Ships for which the required section modulus is based on the maximum bending moments and shear forces occurring when the ships are being loaded and/or discharged according to the loading sequence ‘O’, *see Pt 3, Ch 4, 2.2 Definition of loading sequences ‘T’, ‘O’ and ‘D’* and/or ship type Chapter.

Category ‘D’

At special request, acceptance of the required section modulus on the basis of lower design bending moment and shear forces than those associated with the loading sequence ‘T’, will be considered. However, these bending moments are generally not to be less than as given for MH_{li} and MS_{lo} in *Table 4.5.2 Design bending moments in relation to longitudinal strength category*. Where the notation L.S.‘D’ is assigned, a manual containing approved loading conditions as well as approved loading and discharge sequences is to be carried on board.

At special request, acceptance of the required section modulus on the basis of lower design bending moment and shear forces than those associated with the loading sequence ‘T’, will be considered. However, these bending moments are generally not to be less than as given for MH_{li} and MS_{lo} in *Table 4.5.2 Design bending moments in relation to longitudinal strength category*. Where the notation L.S. ‘D’ is assigned, a manual containing approved loading conditions as well as approved loading and discharge sequences is to be carried on board.

2.4 Specified non-uniform loading conditions

2.4.1 At special request the longitudinal strength, i.e. the required section modulus, may be based on bending moments and shear forces occurring in unusual and/or non-uniform loading conditions, in addition to those occurring when the ship is being loaded and/or discharged according to the loading sequence ‘T’ or ‘O’ as applicable. These bending moments and shear forces are to be verified by direct calculations and a manual containing the approved loading conditions as well as the approved loading and discharge sequences for the non-uniform conditions is to be carried on board.

2.5 Erections contributing to hull strength

2.5.1 Where a long superstructure or deck-house of a length greater than 0,2*L* is fitted, extending within the 0,5*L* amidships, the longitudinal strength of the hull including the long superstructure or deck-house will be considered in each case, *see also Pt 3, Ch 3, 4 Design loading*.

2.6 Approved calculation systems

2.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

■ *Section 3*
Information required

3.1 List of requirements

3.1.1 The information as required by *Pt 3, Ch 1, 5 Information required* is to be submitted.

3.1.2 For ships of which the design bending moments are to be verified by direct calculation, *see Pt 3, Ch 4, 5 Design bending moments*, the following additional information is to be submitted:

(a) Bonjean data, in tabular form or curves, for the ship at sufficient equally spaced stations forward and aft depending on the shape of the ship.
(b) The actual light weight of the ship and its distribution over the length *L* of the ship. Where an assumed distribution is submitted, data in support of the assumption may be required.
(c) Details of cargo weights and their centres of gravity for each condition indicated in *Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments*.
(d) Details of loading and discharging sequences, if applicable.

Section 4
Hull section modulus

4.1 General

4.1.1 The hull section modulus required over 0,5*L* amidships is to be determined from the design bending moments, sagging or hogging, *see Pt 3, Ch 4, 5 Design bending moments*, considering the additional wave bending moment in *Pt 3, Ch 4, 6.2 Design vertical wave bending moments* in association with a permissible stress as indicated in *Pt 3, Ch 4, 6.5 Permissible hull vertical bending stresses*.

4.1.2 The calculation of the actual hull section modulus is to comply with the requirements of *Pt 3, Ch 3, 3.4 Calculation of hull section modulus*.

4.1.3 Outside 0,5*L* amidships, as a minimum, hull girder bending strength checks are to be carried out at the following locations:

(a) In way of the forward end of the engine room.
(b) In way of the forward end of the foremost cargo hold.
(c) At any locations where there are significant changes in hull cross-section.
(d) At any locations where there are changes in the framing system.

Section 5
Design bending moments

5.1 General

5.1.1 The design bending moments, sagging and hogging, are the maximum moments occurring when the ship is in any condition indicated in *Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments*.

5.1.2 The design bending moments may be determined, using the formulae given in this Section, but will be verified by direct calculations for ships with unusual or non-uniform load distribution and for ships of a length, *L*, exceeding 65 m or as specified in *Pt 4, Ch 5, 4.1 Longitudinal strength requirements*, *Pt 4, Ch 6, 2.1 Longitudinal strength requirements* and *Pt 4, Ch 7, 3.1 General 3.1.1*.

5.2 Calculation of design bending moment using formulae

5.2.1 The design bending moments (still water condition) to be distinguished and the formulae to be used are given in *Table 4.5.1 Design bending moments* and *Table 4.5.2 Design bending moments in relation to longitudinal strength category*.

Table 4.5.1 Design bending moments

	Self-propelled ships		Non-propelled ships	
	Hogging	Sagging	Hogging	Sagging
Ships of longitudinal strength, Category 'T'	MH_T	The greater of: MS_T, or MS_{lo}	MH_T	MS_T
Ships of longitudinal strength, Category 'O'	MH_O	MS_O	MH_O	MS_O
Symbols (applicable to *Table 4.5.1 Design bending moments* and *Table 4.5.2 Design bending moments in relation to longitudinal strength category*)				
L, *B*, *D* ,*T* and C_b are defined in *Pt 3, Ch 1, 6 Definitions*				

r	=	ratio of $\frac{L_c}{L}$
L_c	=	length of hold(s) for dry cargo ships
	=	cargo compartment length excluding cofferdams at fore and aft end for tankers
MH_{li}	=	Hogging moment in light condition, *see Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments 2.1.1*
MH_O	=	Hogging moment of ships with loading sequence 'O', *see Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments 2.1.1.(c)*
MH_T	=	Hogging moment of ships with loading sequence 'T', *see Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments 2.1.1.(c)*
MS_{lo}	=	Sagging moment in fully loaded condition, *see Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments 2.1.1.(b)*
MS_O	=	Sagging moment of ships with loading sequence 'O', *see Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments 2.1.1.(c)*
MS_T	=	Sagging moment of ships with loading sequence 'T', *see Pt 3, Ch 4, 2.1 Loading conditions for determination of design bending moments 2.1.1.(c)*

Table 4.5.2 Design bending moments in relation to longitudinal strength category

Moment, in tonne-f m	Self-propelled ships	Non-propelled ships
MH_{li}	$(0,9 – 0,0013L) \times MH_O$	
MH_O	$(1,98r – 0,45) (K_1 BT + K_2) L^2$	$(0,0166 – 0,0088C_b) L^2 BT \times (3,97r - 2,414)$
MH_T	$0,92 \times MH_O$	$(2,23 - 1,67C_b) MH_O$
MS_{lo}	$(0,118C_b - 0,0958)L^2 BT + 0,092 (0,73 - r) L^2 BT$	$(0,95C_b – 0,0806) L^2 BT + 0,1 (0,86 – r)L^2 BT$
MS_O	$(K_3 BT – K_4) L^2 + (0,24C_b – 0,148) (0,73 – r) \times L^2 BT$	$(0,091C_b – 0,068) L^2 BT \times (4,18 – 3,7r)$
MS_T	$(2C_b – 1,08) \times MS_O$	$(2C_b – 1,08) MS_O$
For symbols, *see Table 4.5.1 Design bending moments* and *Table 4.5.3 Self-propelled ships with machinery aft*		

Table 4.5.3 Self-propelled ships with machinery aft

Block coefficient C_b	Hogging moment		Sagging moment	
	K_1	K_2	K_3	K_4
0,75	0,01039	0,07512	0,00668	0,08080
0,76	0,01050	0,07329	0,00741	0,08149
0,77	0,01058	0,07147	0,00817	0,08217

0,78	0,01064	0,06964	0,00895	0,08284
0,79	0,01067	0,06782	0,00975	0,08350
0,80	0,01068	0,06599	0,01056	0,08415
0,81	0,01066	0,06416	0,01139	0,08479
0,82	0,01061	0,06234	0,01225	0,08542
0,83	0,01054	0,06052	0,01312	0,08604
0,84	0,01044	0,05869	0,01401	0,08665
0,85	0,01031	0,05687	0,01492	0,08724
0,86	0,01015	0,05504	0,01584	0,08783
0,87	0,00997	0,05322	0,01679	0,08841
0,88	0,00976	0,05140	0,01775	0,08898
0,89	0,00953	0,04958	0,01874	0,08953
0,90	0,00927	0,04775	0,01974	0,09000
0,91	0,00898	0,04593	0,02076	0,09062
0,92	0,00867	0,04411	0,02180	0,09114
0,93	0,00833	0,04229	0,02286	0,09166
0,94	0,00796	0,04047	0,02394	0,09217
0,95	0,00757	0,03865	0,02504	0,09266

■ *Section 6*
Hull bending strength

6.1 Symbols

6.1.1 The symbols used in this Section are defined as follows:

f_1 = ship service factor

f_2 = wave bending moment factor

M_s = design still water bending moment, sagging (negative) and hogging (positive), in kN m, to be taken negative or positive according to the convention given in *Pt 3, Ch 4, 6.3 Design still water bending moments*

$\overline{Ms}$ = maximum permissible still water bending moment, sagging (negative) and hogging (positive), in kN m

M_w = design hull vertical wave bending moment, sagging (negative) and hogging (positive), in kN m, to be taken negative or positive according to the convention given in *Pt 3, Ch 4, 6.2 Design vertical wave bending moments*

Z_c = actual hull section modulus, in m^3, at continuous strength member above strength deck, calculated with the lever specified in *Pt 3, Ch 3, 3.4 Calculation of hull section modulus*

Z_D, Z_B = actual hull section moduli, in m^3, at strength deck and keel respectively, *see Pt 3, Ch 3, 3.4 Calculation of hull section modulus*

σ = permissible combined stress (still water plus wave), in N/mm^2, *see Pt 3, Ch 4, 6.5 Permissible hull vertical bending stresses*

σ_D, σ_B = maximum hull vertical bending stress at strength deck and keel respectively, in N/mm^2

z = vertical distance from the hull transverse neutral axis to the position considered, in metres

z_M = vertical distance, in metres, from the hull transverse neutral axis to the minimum limit of higher tensile steel, as defined in *Pt 3, Ch 3, 2.6 Vertical extent of higher tensile steel*, above or below the neutral axis as appropriate.

6.2 Design vertical wave bending moments

6.2.1 The appropriate hogging or sagging design hull vertical wave bending moment at amidships is given by the following:

$M_w = f_1 \, f_2 \, M_{wo}$

where

M_{wo} = $0{,}1 C_1 C_2 L^2 B (C_b + 0{,}7)$ kN m

= $(0{,}0102 C_1 C_2 L^2 B (C_b + 0{,}7)$ tonne-f m)

C_b = is to be taken not less than 0,60

C_1 = is given in *Pt 3, Ch 4, 6.2 Design vertical wave bending moments 6.2.1*

C_2 = 1 (also defined in *Pt 3, Ch 4, 6.2 Design vertical wave bending moments 6.2.2* at other positions along the length L)

f_1 = ship service factor. For Zone 3 f_1 = 0,100, for Zone 2 f_1 = 0,207, for Zone 1 f_1 = 0,311

f_2 = –1,1 for sagging (negative) moment

f_2 = $\dfrac{1{,}9 C_b}{(C_b + 0{,}7)}$ for hogging (positive) moment

Table 4.6.1 Wave bending moment factor

Length L, in meters	Factor C_1	
< 90	$0{,}0412L + 4{,}0$	
90 to 135	$10{,}75 - \left(\dfrac{300 - L}{100}\right)^{1{,}5}$	

6.2.2 The longitudinal distribution factor, C_2, of wave bending moment is to be taken as follows:

- 0 at the aft end of L;
- 1,0 between 0,4L and 0,65L from aft;
- 0 at the forward end of L.

Intermediate values are to be determined by linear interpolation.

6.2.3 For harbour the condition, a higher permissible still water bending moment can be assigned based on a reduced vertical wave bending moment given by:

(a) For harbour condition,

$M_w = 0{,}5 f_1 f_2 M_{wo}$

6.3 Design still water bending moments

6.3.1 The design still water bending moment, M_S, hogging and sagging is the maximum moment calculated from the loading conditions, given in *Pt 3, Ch 4, 6.3 Design still water bending moments 6.3.3*, and is to satisfy the following relationship:

$$[M_s] \leq |\overline{M_s}|$$

6.3.2 Still water bending moments are to be calculated along the ship length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of *L*. Hogging bending moments are positive.

6.3.3 In general, the following loading conditions, based on amounts of bunkers, fresh water and stores at departure and arrival, are to be considered:

(a) Homogeneous loading conditions, at maximum draught.
   (i) For non-propelled carriers, the vessel is considered to be homogeneously loaded at its maximum draught, without supplies nor ballast.
   (ii) For self-propelled carriers, the vessel is considered to be homogeneously loaded at its maximum draught with 10 per cent of supplies (without ballast).
(b) Ballast conditions.
(c) Special loading conditions, e.g. container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc. where applicable.
(d) Loading/unloading in two runs or in one run according to the defined loading sequence in *Pt 3, Ch 4, 2.3 Longitudinal strength categories*. The vertical wave bending moment for the harbour condition in *Pt 3, Ch 4, 6.2 Design vertical wave bending moments 6.2.3* might be used in case.
(e) Any other loading condition likely to result in high bending moments and/or shear forces (including docking conditions, as appropriate).

6.3.4 Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or de-ballasting is intended during the voyage, calculations of the intermediate condition just before and just after ballasting and/or de-ballasting any tank are to be submitted and, where approved, included in the loading manual for guidance.

6.4 Permissible still water bending moments

6.4.1 The permissible still water bending moments sagging and hogging are to be taken as the lesser of the following:

(a) $|\overline{M_s}| = \sigma Z_D \times 10^3 - |M_w|$ kN m

(b) $|\overline{M_s}| = \sigma Z_B \times 10^3 - |M_w|$ kN m

where

σ = the permissible combined stress in N/mm^2 as given in *Pt 3, Ch 4, 6.5 Permissible hull vertical bending stresses*. M_W is the design wave bending moment, sagging or hogging as appropriate, in accordance with *Pt 3, Ch 4, 6.2 Design vertical wave bending moments*.

6.5 Permissible hull vertical bending stresses

6.5.1 The permissible combined (still water plus wave) stress for hull vertical bending, σ, is given by:

(a) Longitudinal bending:

$$\sigma_s = \frac{175}{k_L} \text{ N/mm}^2$$

(b) In ships with continuous hatch coamings:

Longitudinal bending at top of coaming

$$\sigma_s = \frac{175}{k_L} \text{N/mm}^2$$

6.5.2 The permissible combined stress σ_c being the sum of stresses due to longitudinal bending and local loading ($\sigma_c = \sigma_s + \sigma_b$) is:

$$\sigma_c = \frac{215}{k_L} \text{N/mm}^2$$

6.5.3 For additional maximum stress requirements, *see* respective ship type Chapter.

Section 7
Hull buckling strength

7.1 Application

7.1.1 These requirements apply to plate panels and longitudinals subjected to hull girder compression based on design values for still water and wave bending moments.

7.2 Symbols

7.2.1 The symbols used in this Section are defined as follows:

d_t = standard addition for corrosion, *see Table 4.7.1 Corrosion additions for one side exposure, dt1 or dt2*

s = spacing of secondary stiffeners, in mm. In the case of symmetrical corrugations, s is to be taken as b or c in *Figure* , whichever is the greater

t = as built thickness of plating, stiffener flange and web used in *Table 4.7.1 Corrosion additions for one side exposure, dt1 or dt2*, in calculating standard addition dt, in mm

t_p = as built thickness of plating less standard addition dt, in mm (i.e. $t_p = t - d_t$)

E = modulus of elasticity, in N/mm^2
= 206000 N/mm^2 for steel
= 69000 N/mm^2 for aluminium alloys

S = spacing of primary members, in metres

σ_o = specified minimum yield stress, in N/mm^2

σ_A = design longitudinal compressive stress in N/mm^2

σ_{CRB} = critical buckling stress in compression, in N/mm^2, corrected for yielding effects

σ_E = elastic critical buckling stress in compression, in N/mm^2

7.3 Corrosion additions

7.3.1 The designer may define values of corrosion additions greater than those specified in *Pt 3, Ch 4, 7.3 Corrosion additions 7.3.2*

7.3.2 The corrosion addition for each of the two sides of a structural member for steel other than stainless steel, t_{d1} or t_{d2}, is specified in *Table 4.7.1 Corrosion additions for one side exposure, dt1 or dt2*.

7.3.3 or plating with a net thickness greater than 8 mm, the total corrosion addition td, in mm, for both sides of the structural member is obtained by the following formula:

$t_d = t_{d1} + t_{d2}$

7.3.4 For plating with a net thickness less than or equal to 8 mm, the smaller of the following values is to be applied for the total corrosion addition t_d:

(a) 20 per cent of the gross thickness of the plating, or

(b) $t_d = t_{d1} + t_{d2}$.

7.3.5 For an internal member within a given compartment, the total corrosion addition t_d is obtained from the following formula:

$t_d = 2t_{d1}$

7.3.6 When a structural element is affected by more than one value of corrosion addition (e.g. plate in a dry bulk cargo hold extending into the double bottom), the scantling criteria are generally to be applied considering the severest value of corrosion addition applicable to the member.

7.3.7 For structural members made of stainless steel or aluminium alloys, the corrosion addition is to be taken equal to 0,25 mm, for one side exposure ($t_{d1} = t_{d2} = 0{,}25$ mm).

7.4 Elastic critical buckling stress

7.4.1 The elastic critical buckling stress of plating is to be determined from *Table 4.7.2 Elastic critical buckling strength of plating*.

7.4.2 The elastic critical buckling stress of longitudinals is to be determined from *Table 4.7.3 Elastic critical buckling strength of longitudinals*.

7.4.3 Alternatively, the elastic critical buckling stress of plating and longitudinals may be assessed in accordance with Chapter 3 of the ShipRight Procedure *Additional Calculation Procedures for Longitudinal Strength*.

7.5 Design stress

7.5.1 Design longitudinal compressive stress, sA, is to be determined in accordance with *Pt 3, Ch 4, 6.5 Permissible hull vertical bending stresses*:

for structural members above the neutral axis,

$$\sigma_A = \sigma_D \frac{z}{z_D}$$

for structural members below the neutral axis,

$$\sigma_A = \sigma_B \frac{z}{z_B}$$

σ_D based on sagging moment and σ_B based on hogging moment are determined by the hull moment of inertia.

where

z = vertical distance from the hull transverse neutral axis to the position considered, excluding deck camber, in metres

z_D, z_B = vertical distances from the hull transverse neutral axis to the deck and keel respectively, in metres

For initial design purposes, the hull transverse neutral axis may be taken at a distance $\frac{D}{2}$ above keel, where *D* is the depth of the ship, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*.

Table 4.7.1 Corrosion additions for one side exposure, dt1 or dt2

Compartment type		General Note 1d
Ballast tank		1,00
Cargo tank and fuel oil tank	Plating of horizontal surfaces	0,75
	Plating of non-horizontal surfaces	0,50
	Ordinary stiffeners and primary supporting members	0,50

Dry bulk cargo hold	General	1,00
	Inner bottom plating Side plating for single hull vessel Inner side plating for double hull vessel Transverse bulkhead plating	1,25
	Frames, ordinary stiffeners and primary supporting members	0,50
Hopper well of dredging vessels		1,75
Accommodation space		0,00
Compartments and areas other than those mentioned above		0,50
Note 1. Corrosion additions are applicable to all members of the considered item.		

Table 4.7.2 Elastic critical buckling strength of plating

Mode	Elastic critical buckling stress, N/mm^2
(a) Compression of plating with longitudinal stiffeners (parallel t compressive stress), *see* Note	$\sigma_E = 3,6E\left(\frac{t_p}{s}\right)^2$
(b) Compression of plating with transverse stiffeners (perpendicular to compressive stress), *see* Note	$\sigma_E = 0,9c\left[1+\left(\frac{s}{1000S}\right)^2\right]^2 E\left(\frac{t_p}{s}\right)^2$ c = 1,3 when plating stiffened by floors or deep girders = 1,21 when stiffeners are built-up profiles or rolled angles = 1,10 when stiffeners are bulb plates = 1,05 when stiffeners are flat bars
Note Where the elastic critical buckling stress, as evaluated from (a) or (b), exceeds 50% of the specified minimum yield stress of the material, the corrected critical buckling stresses in compression (σ_{CRB}) are given by: σ_{CRB} = σ_E when $\sigma_E \le \frac{\sigma_o}{2}$ N/mm^2 = $\sigma_o\left(1-\frac{\sigma_o}{4\sigma_R}\right)$ when $\sigma_E > \frac{\sigma_o}{2}$ N/mm^2	

Table 4.7.3 Elastic critical buckling strength of longitudinals

Mode	Elastic critical buckling stress, N/mm^2
(a) Column buckling (perpendicular to plane of plating) without rotation of cross section, *see* Note 1	$\sigma_E = 0,001E\frac{I_a}{A_t S^2}$
(b) Web buckling, *see* Notes 1 and 3 (flat bars are excluded)	$\sigma_E = 3,8E\left(\frac{t_w}{d_w}\right)^2$
Symbols and parameters	

d_w = web depth, in mm

t_s = as built web thickness less standard addition d_t as specified in *Table 4.7.1 Corrosion additions for one side exposure, dt1 or dt2*, in mm, (i.e. $t_w = t - d_t$). For webs in which the thickness varies, a mean thickness is to be used

A_t = cross-sectional area, in cm^2, of longitudinal, including attached plating, taking account of standard additions, *see* Note 4

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating, taking account of standard additions, *see* Note 4

All other symbols as defined in *Pt 3, Ch 4, 7.2 Symbols 7.2.1*.

Note 1. Where the elastic critical buckling stress, as evaluated from (a) or (b), exceeds 50% of the specified minimum yield stress of the material, the corrected critical buckling stress in compression (σ_{CRB}) is given by:

$$\sigma_{CRB} = \sigma_O\left(1 - \frac{\sigma_O}{4\sigma_R}\right) \text{N/mm}^2$$

2

Note 2. For flanges on angles and T-sections of longitudinals, the following requirement is to be satisfied: $\frac{b_f}{t} \leq$ for angles, $\frac{b_f}{t} \leq 30$ for 'Tee' profiles

where

t = as built flange thicknesses, in mm

Note 3. The area of attached plating is to be calculated using actual spacing of secondary stiffeners.

7.6 Scantling criteria

7.6.1 The corrected critical buckling stress in compression, σ_{CRB}, of plate panels and longitudinals, as derived from *Table 4.7.2 Elastic critical buckling strength of plating* and *Table 4.7.3 Elastic critical buckling strength of longitudinals*, is to satisfy the following:

$$\sigma_{CRB} \geq \beta\sigma_A$$

β = 1,05 for plating and for web plating of longitudinals (local buckling)

β = 1,1 for longitudinals

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ships covered by *Pt 4 Ship Structures (Ship Types)* except where otherwise specifically stated.

1.1.2 The requirements given are those specific to the fore end and aft end regions, *see Pt 3, Ch 3, 2.3 Definition of fore end region* and *Pt 3, Ch 3, 2.4 Definition of aft end region*.

1.1.3 Requirements for the cargo space structure are as detailed in the relevant Chapters of *Pt 4 Ship Structures (Ship Types)* for the particular ship type.

1.2 Structural configuration

1.2.1 The Rules provide for both longitudinal and transverse framing systems or a combination of both.

1.3 Structural continuity

1.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

1.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

1.3.3 Where steps or breaks are situated in the upper deck, suitable scarfing arrangements are to be provided, and the sheerstrake is to be increased in thickness in this region. This also applies to the ends of a trunk deck.

1.3.4 In ships having continuous side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are to be continued as far forward and aft as is practicable and are to be suitably tapered at their ends. Where, due to the ship’s form, these bulkheads are stepped, suitable scarfing is to be arranged.

1.4 Symbols and definitions

1.4.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D and T are as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

s = spacing of secondary stiffeners, i.e. frames, beams, or stiffeners, in metres

S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs, etc. in metres

l = overall length of stiffening member, in metres, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

t = thickness of plating, in mm

P_p = maximum designed shaft power of the propulsion machinery installed in the ship, in kW

H_p = maximum designed shaft power, in shp, of propulsion machinery installed in the ship

1.4.2 For the purpose of this Chapter the forward perpendicular (F.P.) is defined as the forward limit of the Rule length L, and the aft perpendicular (A.P.) is defined as the after limit of the Rule length L.

■ *Section 2* Hull envelope plating

2.1 General

2.1.1 This Section covers the requirements for hull envelope plating, which includes keel, stem, bottom shell plating, bilge plating, side shell plating, sheerstrake and deck plating for the fore end and aft end of the ship. Requirements are also given for tapering between the end thickness and the midship 0,5L thickness.

2.2 Keel

2.2.1 The scantlings of bar keels at the ends are to comply with *Table 5.2.1 Shell plating forward and aft*.

Table 5.2.1 Shell plating forward and aft

Location	Scantlings
(1) Keel bars	t = 0,37L + 10 mm Height = 0,7L + 75 mm
(2) Stem	The greater of:
(a) Bar stem	A = 0,6L cm^2 A = 10 cm^2
(b) Plate stem	t = 0,08L + 5 mm
(3) Bottom shell, bilge and side shell plating forward and aft of the respective shoulders	
(a) Forward of 0,075L from the F.P. and aft of 0,075L from the A.P. (end thickness)	The greater of: $t = (5,6 + 0,054L)\sqrt{sk}$ mm t = 10s mm
(b) Between 0,075L and 0,25L from the F.P. and between 0,075L and 0,25L from the A.P.	The taper thickness as determined from the midship thickness and the end thickness using a taper line as per *Pt 3, Ch 3, 2.5 Principles for taper*
(4) Bilge chine bars	The greater of:

(a) Round bars	Diameter = $3t_a$ mm Diameter = 30 mm
(b) Solid square bars	The greater of: Width = $3t_a$ mm Width = 30 mm
(c) Angle bars in square bilges	Flange thickness = $2t_a$ mm
Symbols	
L, *s* and *t* as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* A = cross sectional area of bar stem, in cm^2 t_a = thickness of the bottom plating amidships, in mm k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*	

2.2.2 The thickness of the keel plate forward of the collision bulkhead is to be the stem plate thickness; aft of the collision bulkhead the keel plate thickness is to be as required for the midship region. The width of the keel plate is to be 0,1*B* at the collision bulkhead and may be tapered towards the stem.

2.2.3 The thickness of the keel plate aft is to be as required for the midship region. The width of the keel plate is to be 0,1*B* at the aft peak bulkhead and may be tapered towards the aft end.

2.3 Stem

2.3.1 Bar stems may be rolled steel bars or steel forgings complying with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* (hereinafter referred to as Rules for Materials). The scantlings of bar stems are to comply with *Table 5.2.1 Shell plating forward and aft*.

2.3.2 The thickness of plate stems is to be determined from *Table 5.2.1 Shell plating forward and aft*. Plate stems are to be supported by horizontal diaphragms, spaced about 1 m apart and extended to the nearest frame. Where the stem plate radius is large, a centreline stiffener or web will be required. The thickness of plate stems from 1 m above the deepest load waterline may be equal to the local shell thickness.

2.3.3 For sternframe details, *see Pt 3, Ch 5, 8 Sternframes and appendages*.

2.4 Shell plating

2.4.1 The thickness of bottom shell, bilge and side shell plating in the forward and aft region is to comply with *Table 5.2.1 Shell plating forward and aft*, but may require to be increased as per *Pt 3, Ch 5, 4.2 Shell framing 4.2.3*.

2.4.2 The amidships thickness of the bilge plating is to be extended forward and aft to include the shoulders of the bilge. The shoulder is regarded to extend to where the upper edge of the bilge strake forward and aft reaches the point 0,5*B* — 0,5 m.

2.4.3 Where a bilge chine bar is used in a bilge arrangement, the scantlings of chine bars are to comply with *Table 5.2.1 Shell plating forward and aft*, and adjacent bottom and side shell plating need not be increased in thickness.

2.4.4 The thickness of side shell and sheerstrake plating in the forward and aft region may require to be increased locally in accordance with *Pt 3, Ch 4 Longitudinal Strength*, on account of high shear forces, or the presence of steps or breaks in decks, *see Pt 3, Ch 5, 1.3 Structural continuity 1.3.3*.

2.4.5 The thickness of shell plating is to be increased locally in way of the sternframe, propeller brackets and rudder trunks. The increased plate thickness is to be not less than 50 per cent greater than the basic shell end thickness. The shell plating in way of hawse pipes is to be increased in thickness by 3 mm.

2.4.6 Where a swim end is arranged, the bottom shell plating thickness amidships is to be maintained up to the end of the rake plating.

2.5 Shell openings

2.5.1 In general, compensation will not be required for holes in the shell plating forward and aft, provided the holes are of well rounded shape, but reinforcements in way of large openings may be required.

2.6 Deck plating

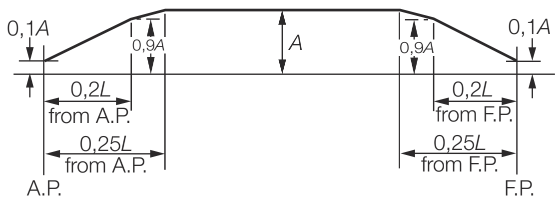
2.6.1 The thickness of deck plating is to comply with the requirements of *Table 5.2.2 Deck plating forward and aft*.

Table 5.2.2 Deck plating forward and aft

Location	Thickness, in mm
(1) Forward of 0,075*L* from the F.P. and aft of 0,075*L* from the A.P. on the strength deck	The greatest of: t = $(5,6 + 0,039L)\sqrt{sk}$ t = $10s$
(2) Between 0,075*L* and 0,25*L* from the F.P. and between 0,075*L* and 0,25*L* from the A.P. on the strength deck	The greatest of: t = $(5,6 + 0,039L)\sqrt{sk}$ t = $10s$ t = the taper thickness *see* Note
(3) Platform decks	The greater of: t = $8s$ t = 3,5
(4) In way of crown or bottom of a tank	The greater of: t = as required in *Pt 3, Ch 7 Bulkheads* t as in (1), (2) or (3) as applicable, but not less than t = 5 mm for oil tanks, or t = 5,5 mm for water ballast tanks
(5) Plating forming the upper flange of under deck girders	The greater of: t = $\sqrt{A_f}$ with a minimum breadth b = 0,75 m t as in (1), (2), (3) or (4) as applicable
Symbols	

L, s and t are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* A_f = girder face area, in cm^2 b = breadth of increased plating, in metres k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*
Note For taper area requirements, *see also Pt 3, Ch 5, 2.6 Deck plating 2.6.2*.

2.6.2 For ships with wide hatch openings, in addition to the requirements for minimum deck thickness forward given in *Pt 3, Ch 5, 2.6 Deck plating 2.6.1*, the total cross-sectional area of strength deck plating and longitudinal stiffening outside the line of main hatch openings is to be not less than that obtained from a taper line constructed as shown in *Figure 5.2.1 Strength deck area taper*.



A = total cross-sectional area of deck plus longitudinal stiffening outside line of main hatch openings amidships

Figure 5.2.1 Strength deck area taper

2.6.3 The deck plating thickness and supporting structure are to be suitably reinforced in way of the anchor windlass, steering gear and other deck machinery, and in way of bollards, cranes, masts or derrick posts.

2.6.4 For steps and breaks, *see Pt 3, Ch 5, 1.3 Structural continuity 1.3.3*.

2.7 Deck openings

2.7.1 Compensation and edge reinforcement for openings in the upper deck forward of 0,25L from the F.P. and aft of 0,25L from the A.P. may be required.

■ *Section 3* Bottom structure

3.1 General

3.1.1 Requirements are given in this Section for both transversely and longitudinally framed bottoms.

3.1.2 Additional requirements for bottom structure in way of the machinery space are given in *Pt 3, Ch 6 Machinery Spaces*.

3.1.3 Provision is to be made for free passage of water, oil and air from all parts of single or double bottoms, and account being taken of the pumping rates required.

3.2 Girders

3.2.1 A centreline girder is to be arranged in ships having a breadth of more than 6 m, and is to be carried as far forward and aft as practicable, and is to comply with the requirements of *Table 5.3.1 Single bottom construction forward and aft* or *Table 5.3.2 Double bottom construction forward and aft*.

Table 5.3.1 Single bottom construction forward and aft

Item	Parameter	Requirements
Transverse framing system		
(1) Floors	Web depth at centreline Modulus Web thickness	$d_{f} = 40 l_f$ mm $Z = 6 \times k \times D_1 \times s \times l_f^2$ cm^3 $t = (0,01 d_f + 2)\sqrt{k}$ mm
(2) Centreline girder	Web and face plate thickness Face plate width	$t = (0,01 d_f + 2)\sqrt{k}$ mm $w = 140s$ mm
Longitudinal framing system		
(3) Centreline girder	Modulus Web thickness	$Z = 8,5 \times k \times D_1 \times S \times l_e^2$ cm^3 $t = (0,01 d_f + 2)\sqrt{k}$
(4) Bottom transverses	Modulus Web thickness	$Z = 7 \times k \times D_1 \times S \times l_e^2$ cm^3 t = as centreline girder
Symbols		
B, D, T, S, s, l_e, Z and t are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* D_1 = D, but need not be taken greater than T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1 d_f = depth of floor or bottom transverse at centreline, in mm l_f = span of the floor, and is normally the breadth of the ship measured on the top of the floor under consideration, in metres. If longitudinal bulkheads or equivalent floor supports are provided an equivalent breadth may be used, but this should be not less than 0,4B w = width of face plate of a member, in mm k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*		
Note The thickness of plates forming the single bottom structure is to be not less than 5 mm.		

Table 5.3.2 Double bottom construction forward and aft

Item	Parameter	Requirements
Transverse and longitudinal framing system		

(1) Centre girder	Least depth	The greater of: $d_f = \dfrac{12 \times D_1 \times l_b^2}{t_1}$ mm mm D_f = 300 mm
	Thickness	$t = \left(0,01 d_f + 2\right)\sqrt{k}$
(2) Inner bottom plating	Thickness for dry spaces	t = 10s
	Thickness for tanks	The greater of: t = 12s mm t = as required by *Pt 3, Ch 7, 2 Scantlings of bulkheads*
(3) Struts	Cross-sectional area	$Area = 2 \times l_e \times D_1 \times s$ cm^2
(4) Watertight floors	Thickness	The thickness of plate floors + 0,5 mm
Transverse framing system		
(5) Plate floors and brackets of bracket floors	Thickness	$t = \left(0,008 d_f + 1\right)\sqrt{k}$ mm
(6) Bottom frames in bracket floors	Modulus	$Z = 6 \times k \times s \times D_1 \times l_e^2 + 1,5 + 0,05L$ cm^3
(7) Reverse frames in bracket floors	Modulus	$Z = 5,5 \times k \times s \times h \times l_e^2 + 1,5 + 0,05L$ cm^3
Longitudinal framing system		
(8) Plate floors	Thickness	$t = \left(0,009 d_f + 1\right)\sqrt{k}$ mm
(9) Tank top longitudinal	Modulus	$Z = 5,5 \times k \times s \times h \times l_e^2 + 1,5 + 0,05L$ cm^3
Symbols		

L, D, T, S, s, t, and Z are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* D_1 = D, but need not be taken greater than T + 0,4 m or Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1 d_f = depth of bottom in way of centre girder, in mm h = load head, which is to be taken as the greater of h_4 or h_5, in metres h_4 = tank head, in metres, as defined in *Pt 3, Ch 3, 4 Design loading* h_5 = distance, in metres, from mid point of span to the deck at side or to a point T + 0,4 m above the baseline, whichever is the lesser, but is to be taken as not less than 1 m l_e = as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1*, but is to be taken as not less than 1,5 m. Struts are not considered as effective supports for the definition of l_e l_b = the width of the double bottom, in metres, and is normally the breadth of the ship. If longitudinal bulkheads or equivalent support is provided, an equivalent breadth may be used, but this should be not less than 0,8B t_1 = thickness of inner bottom plating or bottom plating, whichever is the lesser, in mm k = higher tensilbe steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*
Note The thickness of plating forming the double bottom structure is to be not less than: 5 mm for dry tanks and oil tanks 5,5 mm for water ballast tanks

3.3 Single bottom – Transverse framing

3.3.1 Plate floors are to be fitted at every frame and the scantlings are to comply with the requirements of *Table 5.3.1 Single bottom construction forward and aft*. The depth of floors at the centreline is to be as required in *Table 5.3.1 Single bottom construction forward and aft*, but in ships having considerable rise of floor towards the ends, the depth of floors may require to be increased, or the top edge sloped upwards towards the outboard end, *see Figure 5.3.1 Basic floor arrangements*. If required floors may be cut at the centreline, with the girder web plate continuous, but the strength of the floors is to be maintained in way of the centre girder connection. Notwithstanding the requirements for the fitting of a centreline girder as per *Pt 3, Ch 5, 3.2 Girders 3.2.1*, suitable arrangements to prevent tripping of the floors, e.g. riders or tripping brackets, are to be provided, where the unsupported length of the top edge of the floors exceeds 20b m;

where

b is the width in metres of the face plate of the floor.

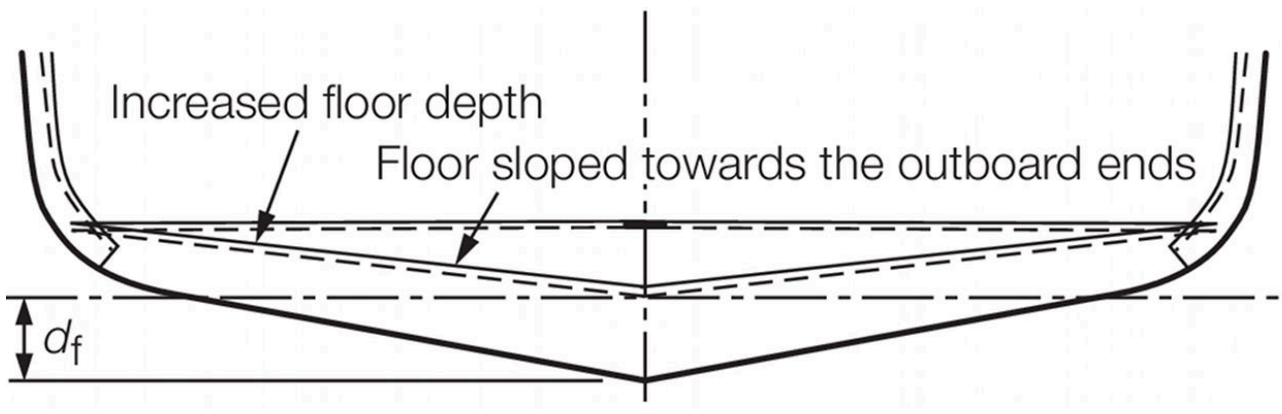


Figure 5.3.1 Basic floor arrangements

3.3.2 The centre girder is to have the same depth as the floors.

3.4 Single bottom - Longitudinal framing

3.4.1 Longitudinals are to be supported by transverses spaced not more than 3,5 m apart. The transverses are to be supported by a primary centreline girder or a centreline bulkhead. Tripping brackets connecting transverse to longitudinal are to be fitted between the centreline girder and shell at intervals not exceeding 3,5 m. The centreline girder may be omitted, provided the scantlings of the transverses are suitable for a span from side to side of the ship, and tripping brackets are fitted about 3,5 m or 20b m apart, whichever is the lesser, where b is the width in metres of the face plate of the transverse. Longitudinals are to be determined from *Table 5.4.1 Shell frames and longitudinals forward and aft*. The scantlings of the centreline girder and bottom transverses are to be determined from *Table 5.3.1 Single bottom construction forward and aft*.

3.5 Double bottoms

3.5.1 Where a double bottom is fitted, the space should be accessible. The minimum depth of the centre girder and the thickness of the centre girder and inner bottom plating are to comply with*Table 5.3.2 Double bottom construction forward and aft*.

3.5.2 Plate floors in a transverse framing system are generally to be fitted at every frame and the scantlings are to comply with the requirements of *Table 5.3.2 Double bottom construction forward and aft*. Vertical stiffeners having a depth of 80d_f mm are to be fitted to the floors and spaced not more than 2,5 m apart. The ends of these stiffeners may be sniped. Alternatively, bracket floors may be fitted, *see Figure 5.3.2 Bracket floor*, in which case the spacing of the plate floors is not to exceed 2,5 m.

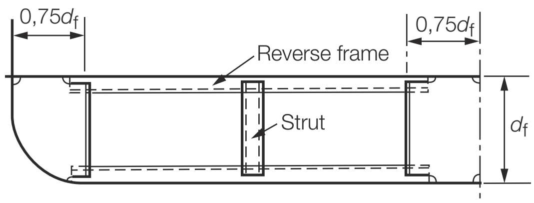


Figure 5.3.2 Bracket floor

3.5.3 Where bracket floors are fitted the unsupported span of bottom frames and reverse frames is not to exceed 2,5 m. Struts may be fitted to reduce the unsupported span. If a strut is fitted at approximately half-span, the modulus of bottom and reverse frames may be reduced by 50 per cent. Struts are to comply with the requirements of *Table 5.3.2 Double bottom construction forward and aft*. Watertight or plate floors are to be fitted below or in the vicinity of watertight bulkheads.

3.5.4 Where a longitudinal framing system is adopted in a double bottom, the scantlings of tank top longitudinals and plate floors are to comply with the requirements given in *Table 5.3.2 Double bottom construction forward and aft*. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. The plate floors are to be spaced not more than 3,5 m apart. The centre girder may require to be stiffened when the height of the bottom is excessive. If a strut is fitted at approximately half-span the modulus of bottom and tank top longitudinals may be reduced by 50 per cent. Struts are to comply with the requirements of *Table 5.3.2 Double bottom construction forward and aft*.

3.6 Swim end forward

3.6.1 Where a longitudinal framing system is adopted, the transverses or floors supporting longitudinals are to be spaced not more than 2,5 m apart, and the moduli of longitudinals and transverses are to be increased by 40 per cent.

3.6.2 Where a transverse framing system is adopted in swim ends, the modulus of plate floors is to be increased by 40 per cent.

3.6.3 The draught for calculation of the structural members may be taken as the actual draught in way of the respective member.

3.6.4 For rake plating, *see Pt 3, Ch 5, 2.4 Shell plating 2.4.6*.

Section 4
Shell envelope framing

4.1 General

4.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried forward and aft to at least the fore end and aft end of the cargo space, including cofferdams in the case of tankers.

4.1.2 For frame spacings, *see Pt 3, Ch 3, 2.9 Frame spacing*.

4.2 Shell framing

4.2.1 The scantlings of side frames in the forward and aft regions are to comply with the requirements given in *Table 5.4.1 Shell frames and longitudinals forward and aft*.

Table 5.4.1 Shell frames and longitudinals forward and aft

Location	Modulus, in cm^3	$I = \frac{3,2}{k} H Z_1{}^4$
(1) Frames clear of tanks	$Z_1 = 1,2 D_1 \times k \times s\ (2,5 H^2 + 0,03 B^2 + 6)$	$I = \frac{3,2}{k} H Z_1$
(2) Frames in way of fuel oil or water tanks	The greater of the following: (a) $Z_2 = Z_1$ (b) Z_2 = as required by *Pt 3, Ch 7 Bulkheads*	$I = \frac{3,2}{k} H Z_1$
(3) Bottom and side shell longitudinals clear of tanks	$Z_3 = 6 \times k \times s \times h_5 \times l_e{}^2 + 1,5 + 0,05L$	$I = \frac{3,2}{k} l_e Z_3$
(4) Bottom and side shell longitudinals in way of tanks	The greater of the following: (a) $Z_4 = Z_3$ (b) Z_4 = as required by *Pt 3, Ch 7 Bulkheads*	$I = \frac{3,2}{k} l_e Z_4$
Symbols		
L, *B*, *D*, *T*, *s*, *Z* and *I* are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1*		
D_1 = *D*, but need not be taken greater than *T* + 0,4 m for Zone 3, *T* + 0,7 m for Zone 2, *T* + 1,0 m for Zone 1		
H = vertical framing depth, in metres, from the top edge of floor or tank top, to the deck at side as shown in *Figure 5.4.1 Framing depth*, *see also* Note 1, but is to be taken as not less than 1,2 m		
h_5 = distance, in metres, from mid point of span to the deck at side or to a point *T* + 0,4 m above the baseline, whichever is the lesser, but is to be taken as not less than 1 m		
l_e = as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* but is to be taken as not less than 1,5 m		
k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*		
Note 1. Where frames are supported by fully effective horizontal stringers, these may be considered as decks for the purpose of determining *H*.		
Note 2. The web depth of frames is to be not less than 45 mm.		

4.2.2 The scantlings of the frames are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets, having arm lengths differing from the standard, are fitted, the frame modulus is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

4.2.3 Where, due to the shape of the vessel at the ends, the distance between frames measured along the shell exceeds the frame spacing, the scantlings of side shell plating and supporting framing structure are to be based on the frame spacing as measured along the shell; alternatively intermediate frames may be fitted or the frame spacing decreased.

4.2.4 The angle between the frame web and the shell plating is to be not less than 50°. Where this angle varies between 70° and 50° the required modulus of the frame is to be corrected as per *Pt 3, Ch 3, 3.2 Geometric properties of section*.

4.2.5 In ships where the angle between the frame web and the shell plating would become less than 50°, the transverse framing, together with attached floors and beams, is to be inclined at an angle to the centreline of ship so that the frames lie as near normal to the shell plating as possible.

4.2.6 Where, due to the curvature or slope of the shell panel, the actual span of the frame measured along the shell is five per cent more than the vertical framing depth as per *Figure 5.4.1 Framing depth*, the modulus of the frame is to be proportionally increased taking into consideration the shape of the frame.

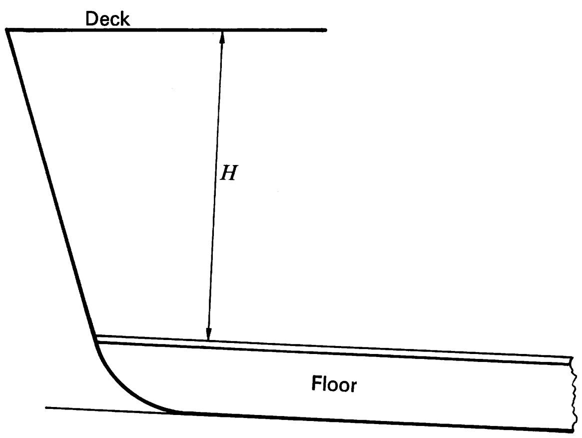


Figure 5.4.1 Framing depth

4.3 Shell longitudinals

4.3.1 The scantlings of bottom and side shell longitudinals are to comply with the requirements given in *Table 5.4.1 Shell frames and longitudinals forward and aft*.

4.3.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as necessary, direct continuity of longitudinal strength, *see also Pt 3, Ch 10, 3 Secondary member end connections*.

4.4 Web frames and side transverses

4.4.1 Web frames are, in general, to be fitted in a transverse framing system, and the scantlings are to comply with the requirements of *Table 5.4.2 Web frames, side transverses and stringers forward and aft*.

Table 5.4.2 Web frames, side transverses and stringers forward and aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Web frames in a transverse framing system	$Z = 2{,}5 \times k \times (2 + n) \times s \times D_2^{\,3}$	$I = \frac{2{,}5}{k} D_2 Z$
(2) Side transverses in a longitudinal framing system	$Z = 7 \times k \times S \times D_2^{\,3}$	$I = \frac{2{,}5}{k} D_2 Z$

(3) Side stringers (fully effective)	$Z = 8 \times k \times S \times h \times l_e^{\,2}$	$I = \frac{2,5}{k} l_e Z$
Symbols		
D, *T*, *S*, *s*, *Z* and *I* are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* D_2 = *D* but need not be taken greater than 1,5 × the effective span of the stiffening member l_e = as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* but is to be taken as not less than 1,5 m *n* = number of frame spaces between the web frames or equivalent structure *h* = load head, which is to be taken as h_4 or h_5 whichever is the greater, in metres h_4 = tank head, in metres, as defined in *Pt 3, Ch 3, 4 Design loading* h_5 = distance, in metres, from mid point of span to the deck at side or to a point *T* + 0,4 m for Zone 3, *T* + 0,7 m for Zone 2, or *T* + 1,0 m for Zone 1 above the baseline, whichever is the lesser, with a minimum of 1 m *k* = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*		
Note 1. The web depth of side transverses is to be not less than twice the depth of the slot for the longitudinal. Note 2. The web depth of fully effective stringers is to be not less than twice the depth of the slot for the frames.		

4.4.2 The spacing of the web frames in a transverse framing system should not exceed 10 frame spaces, but the web frames may be omitted, provided the overall strength is maintained.

4.4.3 The side transverses in a longitudinal framing system are to be spaced not more than 3,5 m apart and the scantlings are to comply with the requirements of *Table 5.4.2 Web frames, side transverses and stringers forward and aft*.

4.4.4 Frames are to be reinforced in way of hatch end beams and deck transverses, and the section modulus should be not less than 0,4 times the section modulus of the deck transverse.

4.4.5 The web thickness, stiffening arrangement and end connections of side transverses and web frames are to be in accordance with the requirements of *Pt 3, Ch 10, 4 Construction details for primary members*.

4.5 Stringers

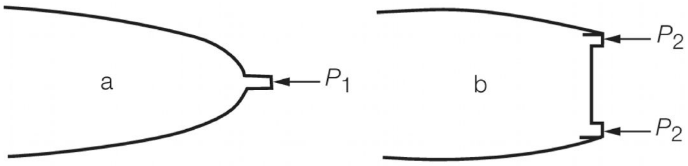
4.5.1 On ships frequently berthing under adverse conditions and where the span of the frames exceeds 2,5 m, an effective stringer is to be fitted in a suitable position.

4.5.2 The scantlings of side stringers, if fitted, are to be determined from *Table 5.4.2 Web frames, side transverses and stringers forward and aft*.

4.6 Stem arrangement for pushing purposes

4.6.1 The structural arrangements are to be such that the stem is adequately supported and integrated into the fore peak structure.

4.6.2 The structure of the stem and the fore peak in way is to be calculated using horizontal loads P_1 or P_2 on the stem as shown in *Figure 5.4.2 Loads on stem for pushing purposes*. The maximum compressive stresses in this structure are not to exceed 78,4 N/mm^2 (800 kg/cm^2).



$$P_1 = \frac{0{,}015 P_p \times L}{B} + 0{,}0136 P_p \text{ tonnes}$$

$$P_2 = \frac{0{,}0098 P_p \times L}{B} + 0{,}0136 P_p \text{ tonnes}$$

$$\left(P = \frac{0{,}011 \times H_p\, L}{B} + 0{,}01 H_p \text{ tonnes} \right)$$

$$\left(P = \frac{0{,}0072 \times H_p \times L}{B} + 0{,}01\ Hp \text{ tonnes} \right)$$

P_p, H_p, L and B are defined in 1.4.1

Figure 5.4.2 Loads on stem for pushing purposes

■ *Section 5* Deck structure

5.1 General

5.1.1 Where the deck, outside the line of openings, is longitudinally framed in the midship region, this system of framing is to be carried as far forward and aft as possible.

5.2 Deck stiffening

5.2.1 The scantlings of deck beams and longitudinals are to comply with the requirements of *Table 5.5.1 Deck beams and longitudinals forward and aft*.

Table 5.5.1 Deck beams and longitudinals forward and aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Transverse beams	$Z = 4{,}3 \times k \times s \times h_1 \times l_e^2 + 1{,}5 + 0{,}05L$	-
(2) Longitudinals	$Z = 4{,}3 \times k \times s \times h_1 \times l_e^2 + 1{,}5 + 0{,}05L$	-
(3) In way of the crown of a tank	Z = as required in *Pt 3, Ch 7 Bulkheads*	$I = \frac{2{,}3}{k} l_e$
Symbols		

L, s, Z and I are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* l_e = as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* but to be taken as not less than 2 m h_1 = head, in metres, as defined in *Pt 3, Ch 3, 4 Design loading* k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*
Note The web depth of beams is to be not less than 45 mm.

5.2.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as necessary, direct continuity of longitudinal strength.

5.2.3 End connections of beams are to be in accordance with the requirements of *Pt 3, Ch 10, 3 Secondary member end connections*.

5.3 Deck supporting structure

5.3.1 Girders and transverses supporting beams and deck longitudinals in the fore ship and aft ship regions, are to comply with the requirements of *Table 5.5.2 Deck supporting structure fore and aft*. In general, transverses, webs or frames of increased scantlings, *see Pt 3, Ch 5, 4.4 Web frames and side transverses*, are to be arranged in way of deck transverses and are to be in line with the floors, where practicable.

Table 5.5.2 Deck supporting structure fore and aft

Item	Parameter	Requirement
Girders and transverses in dry spaces, *see* Note	Modulus	$Z = 4{,}75 \times k \times h_1 \times S \times l_e^{\,2}$ cm^3
	Inertia	$I = \frac{2,3}{k} l_e Z$
Pillars in dry spaces, *see* Note	Cross-sectional area of all types of pillar	$A = \dfrac{k \times P}{1,26 - 4,2\dfrac{l}{r\sqrt{k}}}$ cm^2 cm^4
	Minimum wall thickness of hollow pillars	The greater of (a) and (b): (a) $t = 0{,}033 d_p$ for tubular pillars, mm (b) $t = 0{,}056 b$ for square pillars, mm (c) $t = 5$ mm
Symbols		

S, Z, I and t are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1* b = breadth of side of a hollow rectangular pillar, in mm d_p = mean diameter of tubular pillars, in mm h_1 = head, in metres, as defined in *Pt 3, Ch 3, 4 Design loading* l = overall length of pillar, in m l_e = as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1*, but not less than 2 m r = least radius of gyration of pillar cross-section, in mm, and may be taken as: $r = 10\sqrt{\dfrac{I_p}{A_p}}$ A_p = cross-sectional area of pillar, in cm^2 I_p = least moment of inertia of cross-section, in cm^4 P = load supported by the pillar, in tonne-f k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*
Note For deck supporting structure in tanks, *see also Pt 3, Ch 7 Bulkheads*.

5.3.2 Transverses supporting deck longitudinals are to be spaced not more than 3,5 m apart.

5.3.3 The web thickness, stiffening arrangements and end connections of primary supporting members are to be in accordance with *Pt 3, Ch 10, 4 Construction details for primary members*.

5.3.4 Where a girder or transverse is subjected to concentrated loads, such as pillars or winch seatings, the scantlings are to be determined by direct calculation.

5.3.5 Pillars are to comply with the requirements of *Table 5.5.2 Deck supporting structure fore and aft*.

5.3.6 Pillars are to be fitted in the same vertical line wherever possible, and are to be attached at their heads by efficient brackets, in order to transmit the load effectively. Doubling plates are generally to be fitted under the heels of pillars. The pillars are to have a bearing fit.

5.3.7 The structure in single or double bottoms in way of pillars is to be suitable to support the load imposed on this structure by the pillars.

5.3.8 Where bulkhead stiffeners support pillars, girders or transverses, the stiffeners, in association with a width of plating equal to half the stiffener spacing, should comply with the requirements of *Table 5.5.2 Deck supporting structure fore and aft* for pillars.

■ *Section 6*
Fore peak structure

6.1 General

6.1.1 The requirements in this Section apply to the arrangements of primary structure supporting the peak framing and the scantlings of the collision bulkhead. Furthermore, requirements for wash bulkheads and perforated flats are given.

6.2 Bottom structure

6.2.1 The bottom of the peak space is generally to be transversely framed with arrangements and scantlings as detailed in *Pt 3, Ch 5, 3.3 Single bottom – Transverse framing*.

6.2.2 Where a swim end is arranged in the fore ship and the bottom is longitudinally framed, the longitudinal framing may be extended in the fore peak. The arrangements and scantlings are to be as detailed in *Pt 3, Ch 5, 3.6 Swim end forward* and *Pt 3, Ch 5, 4.3 Shell longitudinals*, but the draught for calculation of the longitudinals and transverses may be taken as the actual draught in way of the member.

6.3 Side structure

6.3.1 The framing in the fore peak may be either transverse or longitudinal but should generally be the same system as the framing aft of the fore peak bulkhead. The scantlings and arrangements of transverse and longitudinal framing are to be as detailed in *Pt 3, Ch 5, 4.2 Shell framing* and *Pt 3, Ch 5, 4.3 Shell longitudinals* respectively.

6.3.2 Transverses supporting side longitudinals are to be fitted not more than 2,5 m apart. Suitable transverses or deep beams are to be arranged at the deck of the fore peak to provide end rigidity to the side transverses.

6.4 Wash bulkheads and perforated flats

6.4.1 Wash bulkheads to support deck beams and/or floors may be fitted in the fore peak and in tanks extending from side to side.

6.4.2 Perforated flats may be fitted in lieu of stringers on shell and bulkheads, *see Pt 3, Ch 5, 4.5 Stringers*.

6.4.3 Wash bulkheads and perforated flats are generally to have an area of perforation between 5 and 10 per cent of their area.

6.4.4 The scantlings of wash bulkheads and perforated flats are to be determined from *Table 5.6.1 Fore peak structure*.

Table 5.6.1 Fore peak structure

Item	Parameter	Requirement
(1) Collision bulkhead	Plating thickness	The greatest of: $t = 4 \times s \times \sqrt{kh_5} + 1{,}5$ mm $t = 5$ mm $t = 5{,}5$ mm for water ballast tanks
	Stiffener modulus	$Z = 4{,}3 \times k \times s \times l_{e1}{}^2 \times h_5 + 4$ cm^3
(2) Perforated flats in void spaces	Plating thickness	The greater of: $t = 7s + 0{,}5$ mm $t = 5$ mm
	Stiffener modulus	$Z = 3{,}5 \times k \times s \times l_{e1}{}^2 + 3$ cm^3
(3) Wash bulkheads and perforated flats in tanks	Plating thickness	The greater of: $t = 7s + 1$ mm $t = 5$ mm
	Stiffener modulus	$Z = 3{,}5 \times k \times s \times l_{e1}{}^2 + 4$ cm^3

Symbols
l_e , s, Z and t are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1*
l_{e1} = l_e but should be taken as not less than 2 m
h_5 = load height, in metres, measured vertically as follows: (i) for vertically stiffened plating – the distance from a point 0,5 m above the lower edge of the plate to a point 1 m above the top of the bulkhead, or to the top of the overflow, whichever is the greater (ii) for horizontally stiffened plating - the distance from the middle of the first panel above the lower edge of the plate to a point 1m above the top of the bulkhead, or to the top of the overflow, whichever is the greater (iii) for stiffeners – the distance from the middle of the effective length to a point 1 m above the top of the bulkhead, or to the top of the overflow whichever is the greater
k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

6.5 Collision bulkhead

6.5.1 The position and height of the collision bulkhead is to be in accordance with the requirements of *Pt 3, Ch 7 Bulkheads*.

6.5.2 The scantlings are to be determined from *Table 5.6.1 Fore peak structure*. End connections of stiffeners are to be in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*.

6.5.3 For requirements regarding openings in the collision bulkhead, *see Pt 3, Ch 7, 1.3 Collision bulkhead 1.3.5*.

■ *Section 7*
Aft peak structure

7.1 General

7.1.1 The requirements given in this Section apply to the arrangements of primary structure supporting the peak framing, the scantlings of the bottom structure, framing, aft peak bulkhead, transom and swim end.

7.2 Bottom structure

7.2.1 The bottom of the peak space is generally to be transversely framed with arrangements and scantlings as detailed in *Pt 3, Ch 5, 3.3 Single bottom – Transverse framing*.

7.2.2 When the ship is self-propelled, the thickness of the floors in the aft peak is to be increased by 15 per cent and the floors are to be suitably stiffened.

7.2.3 Where the bottom in the aft peak is longitudinally framed, the arrangements and scantlings are to be as detailed in *Pt 3, Ch 5, 4.3 Shell longitudinals*; additional bottom transverses are to be fitted in way of rudder posts, propeller posts and shaft brackets if fitted.

7.3 Side structure

7.3.1 The framing in the aft peak may be either transverse or longitudinal. The scantlings and arrangements of the framing are to be as required in *Pt 3, Ch 5, 4.2 Shell framing* and *Pt 3, Ch 5, 4.3 Shell longitudinals* respectively.

7.4 Aft peak bulkhead

7.4.1 The position and height of the aft peak bulkhead and the scantlings are to be in accordance with the requirements of *Pt 3, Ch 7 Bulkheads*. The plating is to be locally increased in way of the sterntube gland.

7.5 Transom

7.5.1 Where a transom is arranged in the aft ship, the scantlings and arrangements of plating and stiffening are to be as detailed in *Pt 3, Ch 5, 2 Hull envelope plating* and *Pt 3, Ch 5, 4 Shell envelope framing* respectively.

7.6 Swim end aft

7.6.1 The draught for calculation of the structural members may be taken as the actual draught in way of the respective member.

7.7 Stern arrangement for pushing purposes

7.7.1 Where the ship is intended to be pushed, the stern arrangement is to comply with the requirements of *Pt 3, Ch 5, 4.6 Stem arrangement for pushing purposes* for the stem arrangement. The forces P_1 or P_2 are to be determined applying a value of $P_p(H_p)$ based on the intended service conditions.

■ *Section 8* Sternframes and appendages

8.1 General

8.1.1 Sternframes, propeller bosses and shaft brackets may be constructed of forged or cast steel, or may be fabricated from plate.

8.1.2 Forgings and castings are to comply with the requirements of *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 4 Longitudinal Strength* of LR's Rules for Materials respectively.

8.1.3 Cast sternframes, rudder horns and solepieces are to be manufactured from special grade material, *see Ch 4, 2 Castings for ship and other structural applications* of the Rules for Materials. Cast bossings can be manufactured from normal grade material, *see Ch 4, 2 Castings for ship and other structural applications* of the Rules for Materials.

8.1.4 Sternframes, shaft brackets, etc. are to be effectively integrated into the ship's structure and their design is to be such as to facilitate this.

8.2 Sternframes

8.2.1 The scantlings of sternframes are to be determined from *Table 5.8.1 Sternframes*. The scantlings for sternframe configurations other than described in this Section, and for cast steel sternframes, will be specially considered, but the strength is to be at least equivalent to a fabricated sternframe.

Table 5.8.1 Sternframes

Item	Parameter	Requirement	
		Forged or roll steel	Fabricated steel
(1) Propeller posts	A	for $L \leq 60$ m : $\left(10+\frac{L}{2}\right)$ 0,8T cm^2	-
	A	for $L > 60$ m : 32T cm^2	-
	t_1	-	12 + 0,11L mm
	r	-	18 + 0,17L mm
	l	-	150 $\sqrt{T}$ mm
	W	-	100 $\sqrt{T}$ mm
	t_W	-	5 + 0,05L mm
(2) Sternpost in twin screw ships and non-propelled ships	A	for $L \leq 60$ m : $\left(10+\frac{L}{2}\right)$ 0,7T cm^2	-
	A	for $L > 60$ m : 28T cm^2	-
	t_1	-	8 + 0,07L mm
	r	-	12 + 0,11L mm
	l	-	150 $\sqrt{T}$ mm
	W	-	100 $\sqrt{T}$ mm
	t_W	-	5 + 0,05L mm
(3) Propeller shaft boss	t_b	$\left(0,25D_{ts}+t_2\right)\sqrt[3]{ek_o}$ mm	
(4) Solepieces (open type sternframe) supporting the lower rudder pintle	Z_T	$c.f.Ar(V + 5,6)^2 \times (a/b - 0,15) \times 0,95\, a/b$ cm^3 *see* Note 4	
	Z_V	0,5Z_T cm^3	
(5) Double arm shaft brackets	Z_T	$(16 \times 10^{-6} \times D_{ts}^{\ 3}) + 8$ cm^3	
	N	$\geq$ 0,05e mm	
	M:N	between 2,5 and 5	
Symbols			

L, *T* are as defined in *Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1*		
a, b, c	=	distances, in metres, as shown in *Figure 5.8.2 Open sternframe*
e	=	length of the longest shaft bracket strut, in mm
f	=	coefficient dependent on type of rudder profile and rudder angle, *see Table 12.2.5 Rudder coefficient f* in Chapter 12 for rudder angles in excess of 45° no higher factors than those for rudder angles of 45° need to be applied.
k_{o}	=	material factor, = $(235/\sigma_{o})$ $(24/\sigma_{o})$
t_{2}	=	10 mm for a propeller shaft boss integrated in the sternframe or supported by a single arm bracket and t_{2} = 0 for a propeller shaft boss supported by double arm shaft brackets.
t_{b}	=	finished thickness of boss, in mm
t_{1}, r, l, W, t_{W}	=	scantlings of stern post, in mm, as shown in *Figure 5.8.1 Propeller posts*
A	=	cross-sectional area of forged or rolled steel stern post, in cm^2
A_{r}	=	total rudder area, in m^2
D_{ts}	=	Required mild steel diameter of tail shaft in way of the boss, in mm
M	=	the breadth of the shaft bracket strut, in mm, for e, M and N, *see also Figure 5.8.3 Shaft brackets*
N	=	the thickness of the shaft bracket strut, in mm
V	=	maximum service speed with the ship in loaded condition, in km/h
Z_{T}	=	section modulus against transverse bending, in cm^3
Z_{V}	=	section modulus against vertical bending, in cm^3
Note 1. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welding.		
Note 2. Solepieces supporting movable nozzles will be specially considered.		
Note 3. The support of a solepiece by a fixed nozzle arrangement will be specially considered.		
Note 4. The length 'a' of the solepiece should be taken as not less than 0,4b in the formula for Z_{T}.		

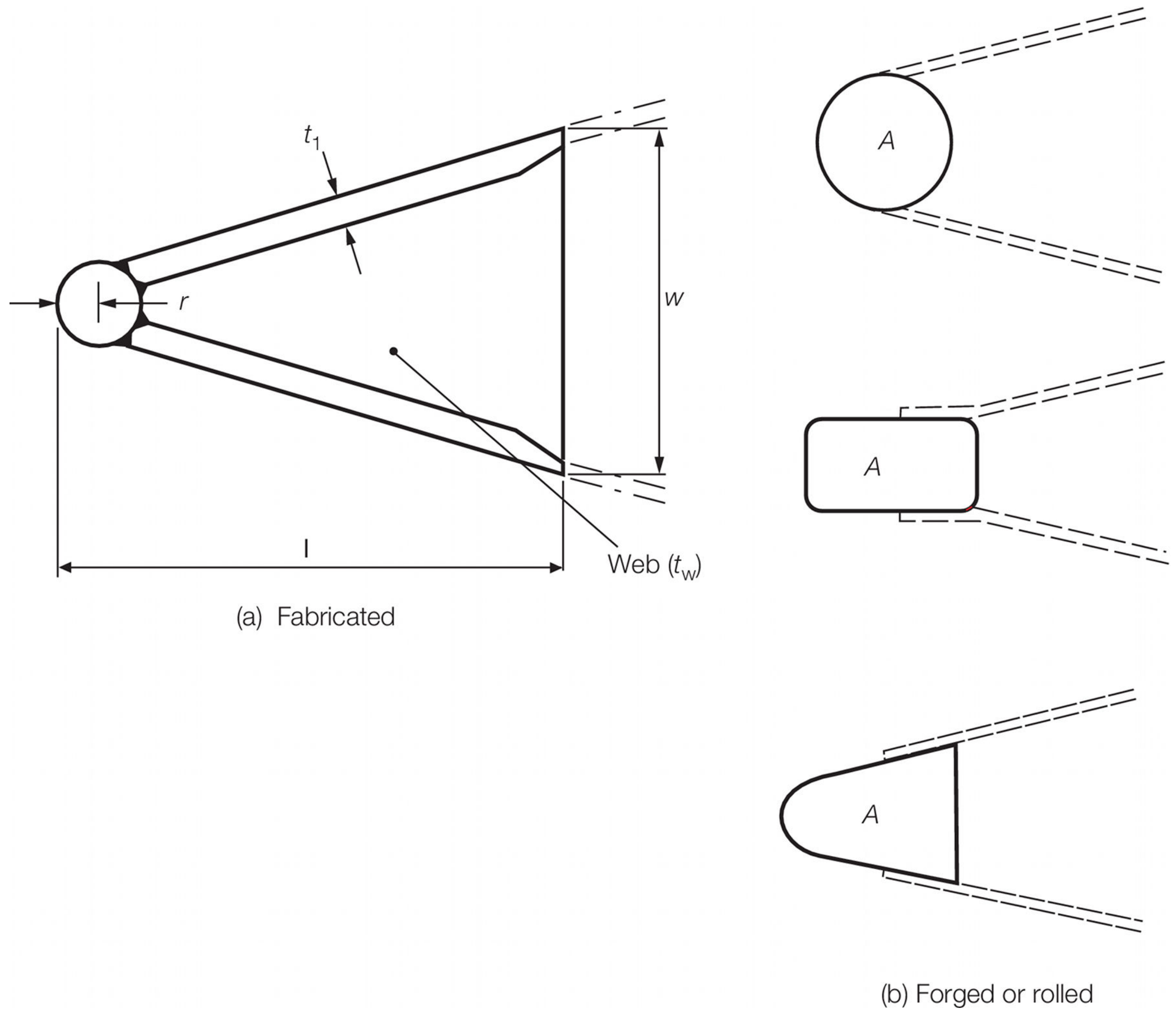


Figure 5.8.1 Propeller posts

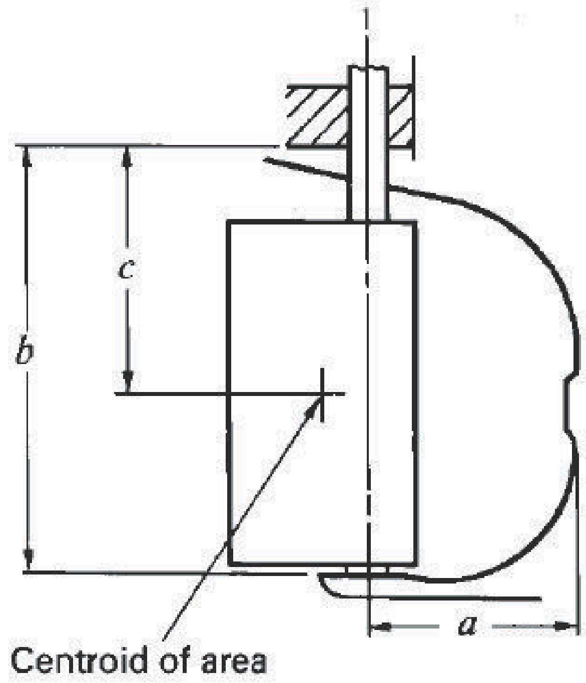


Figure 5.8.2 Open sternframe

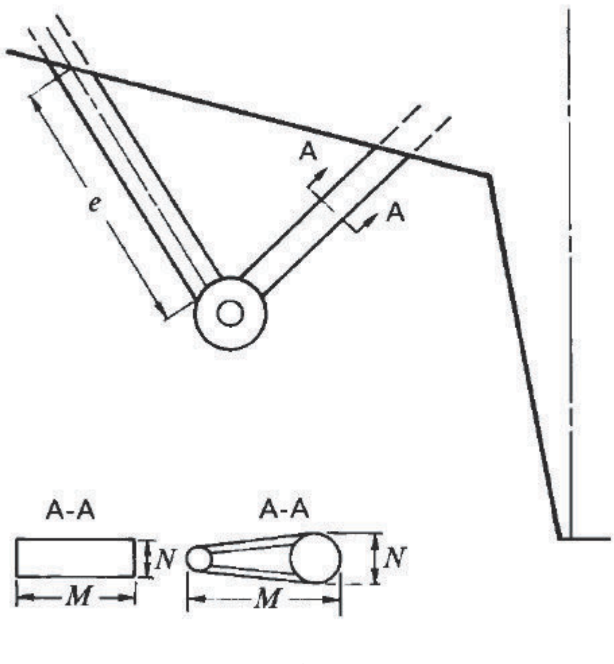


Figure 5.8.3 Shaft brackets

8.2.3 Fabricated sternframes are to be strengthened by transverse webs, spaced not more than 700 mm apart.

8.2.4 Solepieces are to be carried well forward and efficiently scarfed into the keel. Special care is to be taken to avoid any stress-raising details at the point where the solepiece enters the shell plating.

8.2.5 Stern posts and rudder stock lower bearings are to be connected to floors of which the thickness is to be increased by 2 mm, above the thickness required by *Pt 3, Ch 5, 7.2 Bottom structure*.

8.3 Propeller shaft bossing

8.3.1 The finished thickness of the propeller boss in single and twin screw ships is to comply with *Table 5.8.1 Sternframes*. The length of the boss is to be adequate to accommodate the aftermost shaft bearing, and to allow for a proper connection to the propeller post or shaft brackets.

8.4 Shaft brackets

8.4.1 Where the propeller shafting is exposed for some distance clear of the hull, it is to be supported adjacent to the propeller by independent brackets having two arms. The use of single arm brackets will receive special consideration.

8.4.2 Shaft brackets are to be designed to ensure a satisfactory connection to the internal hull structure; hard spots are to be avoided. Bracket arms are generally to be carried through the shell plating, which is to be locally increased in thickness, *see Pt 3, Ch 5, 2.4 Shell plating 2.4.5*. The connection of the arms to the bearing boss and shell plating is to be by full penetration welding.

8.4.3 The scantlings of double arm shaft brackets are to comply with the requirements of *Table 5.8.1 Sternframes*. The scantlings of single arm brackets will be specially considered.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in *Pt 4 Ship Structures (Ship Types)*, with propulsion machinery and/or auxiliary machinery situated in a machinery space. Only the requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see Pt 3, Ch 5 Fore End and Aft End Structure* and the relevant Chapter in *Pt 4 Ship Structures (Ship Types)* for the particular ship type concerned.

1.2 Structural configuration and continuity

1.2.1 The Rules provide for both longitudinal and transverse framing systems or a combination of both.

1.2.2 Where a machinery space is situated aft, and longitudinal bulkheads terminate at or in the machinery space, suitable taper brackets are to be provided at the ends of the bulkheads. Suitable scarfing arrangements are to be provided where a longitudinal framing system terminates at or in the machinery space.

1.2.3 Where a machinery space is situated amidships and the shell and deck outside the line of openings are longitudinally framed, this system of framing is also to be adopted in the machinery space. Longitudinal bulkheads, if fitted, are generally to be carried through the machinery space. Where structure which contributes to the main longitudinal strength of the ship is discontinued in way of a machinery space, suitable compensation and scarfing arrangements are to be provided.

1.3 Symbols and definitions

1.3.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T are as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

s = spacing, of secondary stiffeners, i.e. frames or beams, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

S = spacing or mean spacing of primary members, in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*.

■ Section 2
Deck structure

2.1 Strength deck – Plating

2.1.1 Where a machinery space is situated aft, the deck plating thickness is to be as required in *Pt 3, Ch 5, 2.6 Deck plating*. The corners of deck openings are to be of suitable shape and design to minimize stress concentrations.

2.1.2 Where a machinery space is situated amidships and large openings are provided in the strength deck, the thickness of the deck plating abreast of the openings may require to be increased in thickness above that required in the relevant ship type Chapter in *Pt 4 Ship Structures (Ship Types)*, in order to maintain the strength of the hull girder.

2.2 Lower deck – Plating

2.2.1 The plating of lower decks and flats is to comply with the requirements of *Pt 3, Ch 5, 2.6 Deck plating* or the relevant ship type Chapter in *Pt 4 Ship Structures (Ship Types)*. The thickness of platforms on which auxiliary engines are placed, is to be increased locally by 1 mm.

2.3 Deck stiffening

2.3.1 The section modulus of main deck beams and longitudinals in way of machinery spaces is to be 20 per cent greater than that required by *Pt 3, Ch 5, 5.2 Deck stiffening* or in the relevant ship type Chapter in *Pt 4 Ship Structures (Ship Types)*, but for decks on which auxiliary engines are placed a further increase in way of 20 per cent is required, *see also Pt 3, Ch 6, 5.3 Seats for auxiliary machinery 5.3.1*.

2.4 Deck supporting structure

2.4.1 In addition to the longitudinal girders and transverses, fitted to support the deck structure, deep beams are to be fitted at the fore and aft end of engine casings. Longitudinal girders may require to be fitted in line with the sides of casings. The depth of these deep beams and girders is to be at least twice the depth of the deck beams or longitudinals.

■ Section 3
Side shell structure

3.1 Primary structure

3.1.1 A transverse framing system is to be additionally reinforced by web frames fitted five frame spaces apart. Where a longitudinal framing system is adopted, the spacing of the transverses is not to exceed 2,5 m.

3.1.2 The scantlings of web frames and transverses are to be as required by *Table 6.3.1 Web frames and side transverses in machinery spaces*.

Table 6.3.1 Web frames and side transverses in machinery spaces

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Web frames in a transverse framing system	$Z = 3{,}5 \times (1{,}5 + n) \times k \times s \times D_2{}^3$	$I = \frac{2,5}{k} D_2 Z$
(2) Side transverses in a longitudinal framing system	$Z = 8 \times k \times S \times D_2{}^3$	$I = \frac{2,5}{k} D_2 Z$
Symbols		

D, S, s and Z are as defined in *Pt 3, Ch 6, 1.3 Symbols and definitions 1.3.1* n = number of frame spaces between the web frames or equivalent structure D_2 = D but need not be taken greater than 1,5 times the effective span of the stiffening member k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*
Note The web depth of side transverses is to be not less than twice the depth of the slot for the longitudinal.

■ *Section 4* Single and double bottom structure

4.1 General

4.1.1 This Section applies to transversely and longitudinally framed bottoms.

4.1.2 Where a machinery space is situated in the aft ship, the bottom is generally to be transversely framed. Elsewhere the transverse or longitudinal framing may be adopted.

4.1.3 Care is to be taken that the rigidity of the bottom structure is not impaired by discontinuities such as recesses, lightening holes and large drain holes.

4.1.4 Floors and girders are not to be flanged, but provided with welded face bars.

4.2 Bottom construction

4.2.1 Where the bottom is transversely framed, plate floors are to be fitted at every frame and the scantlings are to comply with the requirements of *Table 6.4.1 Bottom construction in the machinery space*. The thickness of the floors in way of the engine seating is also to comply with the requirements of *Pt 3, Ch 6, 5.2 Seats for main propulsion engines*.

Table 6.4.1 Bottom construction in the machinery space

Item	Parameter	Scantlings
Transverse framing system		
Floors (single bottom)	Web depth at centreline Modulus Web thickness	$d_f = 50 l_f$ mm $Z = 7{,}2 \times k \times D_1 \times s \times l_f^{\,2}$ cm^3 $t = (0{,}01 d_f + 2)\sqrt{k}$ mm
Floors (double bottom)	Web thickness	$t = (0{,}008 d_f + 2)$ mm
Longitudinal framing system		
Bottom transverses	Modulus Web thickness	$Z = 10 \times k \times D_1 \times S \times l_e^{\,2}$ cm^3 $t = (0{,}01 d_f + 2)\sqrt{k}$ mm
Floors (double bottom)	Web thickness	$t = (0{,}01 d_f + 2)\sqrt{k}$ mm
Transverse and longitudinal framing system		

Bottom shell plating in way of engine seating	Minimum thickness	$t = (0{,}03A + 4{,}5)\sqrt{k}$ mm
Symbols		
D, *T*, *S*, *s* and *Z* are as defined in *Pt 3, Ch 6, 1.3 Symbols and definitions 1.3.1* d_f = depth of floor at centreline, in mm l_e = span of bottom transverse, in metres l_f = span of the floor, in metres, and is normally the breadth of the ship measured on top of the floor under consideration. If longitudinal bulkheads or equivalent floor supports are provided, an equivalent breadth may be used, but this should be not less than 0,4*B* *A* = area of engine seating top plate, in cm^2, as required by *Table 6.5.1 Seats for engines* D_1 = *D*, but need not be taken greater than *T* + 0,4 m for Zone 3, *T* + 0,7 m for Zone 2, *T* + 1,0 m for Zone 1 *k* = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*		

4.2.2 Where the bottom amidships is longitudinally framed, the bottom transverses or plate floors in a double bottom abreast the engine seating are to be spaced not more than 1,8 m apart and the thickness is to comply with the requirements of *Table 6.4.1 Bottom construction in the machinery space*. In way of the engine seating, floors are to be fitted at every frame and the thickness is to comply with *Pt 3, Ch 6, 5.2 Seats for main propulsion engines*, *see also Figure 6.4.1 Engine room bottom with longitudinal framing*.

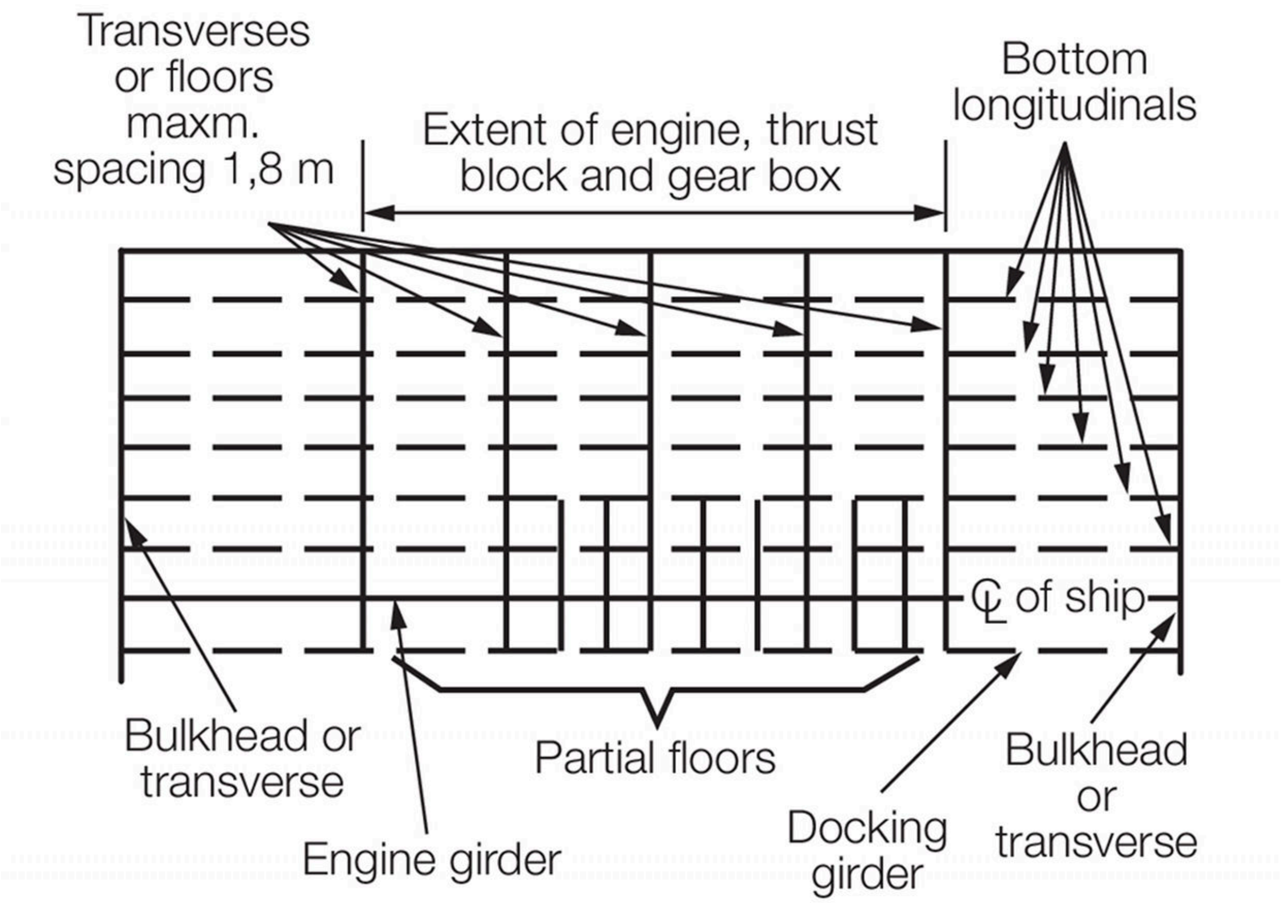


Figure 6.4.1 Engine room bottom with longitudinal framing

4.2.3 The transverse strength of the bottom is also to be maintained when the bottom construction is recessed under the engines.

4.2.4 The centre girder, if required, may be omitted where the engine girders are situated less than 1,5 m from the centreline of the ship, but a docking girder should generally be fitted. Side girders are to be fitted when normally required in the same position.

4.3 Bottom plating

4.3.1 The bottom plating in machinery spaces is to be as required in *Pt 3, Ch 5 Fore End and Aft End Structure* or as in the relevant ship type Chapter in *Pt 4 Ship Structures (Ship Types)*, but the plating in way of the engine seatings is to be not less than required in *Table 6.4.1 Bottom construction in the machinery space*. When the thickness of the bottom plating is to be increased to meet this requirement, the increased plating is to extend for at least two frame spaces beyond the full length of the engine seating and for 1 m on either side of the seating girders.

4.4 Water inlets

4.4.1 Water inlets and other openings such as openings for cooler boxes are to have well rounded corners. The thickness of water inlet and cooler box plating is to be 4 mm greater than the adjacent shell plating, or 12 mm, whichever is the greater. Suitable cathodic protection is to be provided inside the cooler boxes.

Section 5
Engine seatings

5.1 General

5.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

5.2 Seats for main propulsion engines

5.2.1 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and should, in general, extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors, *see Figure 6.5.1 Typical engine seatings*. Small brackets may be required under the top plate in way of holding down bolts.

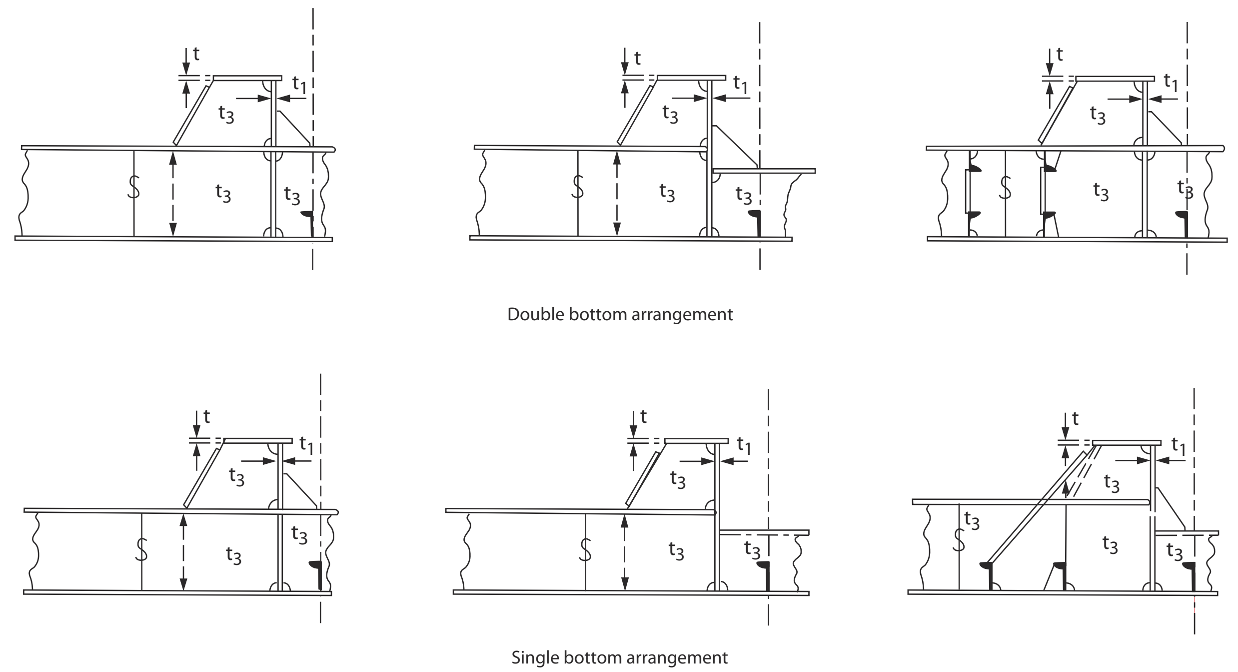


Figure 6.5.1 Typical engine seatings

5.2.2 In determining the scantlings of seats for main propulsion engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics in regard to out of balance forces. As a general guide to designers, minimum scantlings are given in *Table 6.5.1 Seats for engines*.

Table 6.5.1 Seats for engines

Item	Parameter	Scantlings
Top plates	Area for one top plate	$A = f\,(0{,}088P + 25)$ cm^2 $(A = f\,(0{,}065H + 25)$ cm$^2)$
	Minimum thickness	$t = 0{,}1A + 14$ mm
Girders under top plate	Web thickness	$t_1 = 0{,}043A + 7$ mm
Girders fore and aft of engine	Web thickness Face plate area	$t_2 = 0{,}01d_f + 2$ mm $A_1 = 0{,}1A + 4$ cm^2
Floors (in way of seating)	Web thickness	$t_3 = 0{,}02A + 6$ mm or as that required in *Pt 3, Ch 6, 4 Single and double bottom structure*, whichever is the greater
Symbols		
d_f = depth of girder, in mm f = 1,3 – 0,0003R, where R = rev/min of engine at maximum service speed t = minimum thickness of top plate, in mm t_1 = main engine girder thickness, in mm t_2 = thickness of girders in line with engine seating girders, fore and aft of the engine, in mm t_3 = thickness of floor plate in way of seating, in mm A = area of top plate for one side of seat, in cm^2 A_1 = area of girder face plate in, cm^2 P = power of one engine at maximum service speed, in kW (H = power of one engine at maximum service speed, in bhp)		

5.3 Seats for auxiliary machinery

5.3.1 Auxiliary machinery is to be secured to seatings of adequate scantlings, so arranged as to distribute the loads evenly into suitably designed supporting structure. For larger auxiliary machinery the scantlings of *Table 6.5.1 Seats for engines* may be used as a guide.

5.4 Seats for boilers

5.4.1 Boiler bearers are to be of substantial construction and efficiently supported by the ship's structure.

Section 6
Machinery casings and fuel oil tanks

6.1 Machinery casings

6.1.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with *Pt 3, Ch 8, 2 Scantlings of erections*.

6.1.2 The minimum scantlings of protected casings are to be in accordance with *Table 6.6.1 Protected machinery casings*.

Table 6.6.1 Protected machinery casings

Item	Minimum scantlings
Plating	t = 7s mm or t = 3,5 mm whichever is the greater
Stiffeners	Z = 15s + 4 cm^3
Symbols	
Z, t and s are as defined in *Pt 3, Ch 6, 1.3 Symbols and definitions 1.3.1*	
Note The depth of stiffeners is to be not less than 45 mm.	

6.1.3 Where casing stiffeners carry loads from deck transverses, girders, etc. or where they are in line with pillars below, they are to be suitably increased.

6.1.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.2 Fuel oil tanks

6.2.1 Oil tanks integral with the ship's structure in the machinery space are generally to comply with the requirements given in *Pt 3, Ch 7 Bulkheads*.

6.2.2 The scantlings of oil tanks not integral with the ship's structure are to comply with *Pt 5, Ch 12, 4.9 Fresh water piping*.

6.2.3 Where a pipe is fitted in the bilge to facilitate the transition between the horizontally oriented bottom plating and the vertically oriented side shell plating and it passes through fuel oil tanks, small stoppers are to be fitted in the pipes to prevent the passage of fuel to adjacent tanks in case of leakage of the pipe. In this case, small plugs for draining and venting purposes of the individual pipe part contiguous to the fuel oil tanks are to be fitted.

Section 7
Means of escape

7.1 General

7.1.1 In machinery spaces, boiler rooms or under deck pump rooms, two means of escape are generally to be provided. A second means of escape may be dispensed with if:

(a) The total floor area (average length x average width at the level of floor plating) of subject space does not exceed 35 m^2 and
(b) The distance between each point where servicing or maintenance operations are carried out and the exit, or stairs providing access to the outside, is not greater than 5 metres.

■ *Section 1*
General

1.1 Application

1.1.1 The requirements of this Chapter cover the transverse, longitudinal and horizontal boundaries of watertight compartments and deep tanks. Requirements are also given for non-watertight bulkheads. For bulkheads in the cargo compartment space of tankers, see the individual ship type Chapters in *Pt 4 Ship Structures (Ship Types)*.

1.1.2 The requirements of this Chapter apply to vertically stiffened bulkheads. They may also be applied to horizontally stiffened bulkheads provided that equivalent end support is fitted and alignment provided.

1.2 Number and disposition of bulkheads

1.2.1 All ships are to have a collision bulkhead, a watertight bulkhead at each end of the machinery space and an after peak bulkhead. In ships with the machinery space aft, the after peak bulkhead may form the after boundary of the machinery space. Where sterntubes are enclosed in a suitable watertight space, the after peak bulkhead may be omitted in ships as indicated in *Pt 3, Ch 7, 1.4 After peak bulkhead 1.4.1*. Additional bulkheads are to be fitted to provide for sufficient transverse strength of the vessel.

1.2.2 The bulkheads in the holds should be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a hold is unusually great, the transverse strength of the ship is to be maintained by fitting web frames, increased framing, etc. Details are to be submitted for approval.

1.2.3 For subdivision requirements within the cargo tank region of tankers, *see* individual ship type Chapters in *Pt 4 Ship Structures (Ship Types)*.

1.2.4 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability of the National Authority of the country in which the ship is to operate or be registered.

1.3 Collision bulkhead

1.3.1 A collision bulkhead is to be arranged at a suitable distance from the forward perpendicular at a location that, when the fore peak is fully flooded, the buoyancy of the fully loaded vessel is sufficient and a residual safety distance of 100 mm from any opening which cannot be closed weathertight is attained.

1.3.2 As a general rule, the requirement of *Pt 3, Ch 7, 1.3 Collision bulkhead 1.3.1* shall be considered to have been met if the collision bulkhead has been positioned at a distance between 0,04*L* and 0,04*L* + 2 m from the F.P. If the distance exceeds 0,04*L* + 2 m, compliance with *Pt 3, Ch 7, 1.3 Collision bulkhead 1.3.1* shall be proven by direct calculations.

1.3.3 The distance from the F.P. may be reduced to 0,03*L* in which case the requirement of *Pt 3, Ch 7, 1.3 Collision bulkhead 1.3.1* shall be proven by direct calculations based on the flooding of both fore peak and those compartments directly aft of and adjacent to the collision bulkhead.

1.3.4 Special designs or types of ships requiring another position, will be specially considered.

1.3.5 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the uppermost continuous deck.

1.3.6 Any recesses or steps in collision bulkheads are to fall within the limits of bulkhead positions.

1.4 After peak bulkhead

1.4.1 All ships are to have an after peak bulkhead generally enclosing the sterntube and the rudder trunk in a watertight compartment. An after peak bulkhead generally enclosing the sterntube and the rudder trunk in a watertight compartment is to be

arranged at a suitable distance from the stern at a location at which, when the watertight compartment aft of the aft peak bulkhead is fully flooded, the buoyancy of the fully loaded vessel is sufficient, with a residual safety distance of 100 mm from any opening which cannot be closed weathertight is attained. This after peak bulkhead need not be fitted on ships with a length *L* less than 25 m if the stern tube is enclosed in a suitable watertight space. In ships with two or more propellers where the bossing ends forward of the after peak bulkhead, the sterntubes are to be enclosed in a suitable watertight space.

1.4.2 As a general rule, the requirements of *Pt 3, Ch 7, 1.4 After peak bulkhead 1.4.1* shall be considered to have been met if the after peak bulkhead has been positioned at a distance between 0,04*L* and 0,04*L* + 2 m from the aft point of the intersection of the hull with the maximum draught line. If the distance exceeds 0,04*L* + 2 m, compliance with *Pt 3, Ch 7, 1.4 After peak bulkhead 1.4.1* shall be proven by direct calculations.

1.4.3 The distance from the aft point of the intersection of the hull with the maximum draught line may be reduced to 0,04*L* – 1 m, in which case the requirement of *Pt 3, Ch 7, 1.4 After peak bulkhead 1.4.1* shall be proven by direct calculations based on the flooding of both the compartment aft of the aft peak bulkhead and the immediately adjacent compartments.

1.5 Height of bulkheads

1.5.1 All bulkheads are to extend to the uppermost continuous deck. In ships with continuous coamings the transverse hold bulkheads are to extend to the top of the coaming and are to be suitably stiffened at their top edge.

1.6 Protection of tanks carrying fuel oil, lubricating oil, vegetable or similar oils

1.6.1 Cofferdams are required between each tank carrying:

(a) Fuel oil or lubricating oil;
(b) Feed water or fresh water; and
(c) Vegetable or similar edible oils.

However, cofferdams need not be fitted between fuel oil or lubricating oil double bottom tanks and deep tanks carrying feed water, fresh water or vegetable or similar edible oils provided that the double bottom tanks are not interconnected with any tanks above.

1.6.2 Lubricating oil compartments are also to be separated by cofferdams from those carrying fuel oil. However these cofferdams need not be fitted provided that:

(a) Common boundaries of lubricating oil and fuel oil tanks have full penetration welds.
(b) The tanks are arranged such that the fuel oil tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

1.6.3 Cofferdams are required between fuel oil double bottom tanks and deep tanks above when the double bottom tank and side tanks are interconnected.

1.7 Location of tanks

1.7.1 Fuel oil, lubricating oil and hydraulic oil are not to be carried forward of the collision bulkhead.

1.7.2 Fuel tanks and their fittings shall not be located directly above engines or exhaust pipes.

■ *Section 2*
Scantlings of bulkheads

2.1 Watertight and deep tank bulkheads

2.1.1 The scantlings of watertight and deep tank bulkheads are to comply with the requirements of *Table 7.2.1 Watertight and deep tank bulkhead scantlings*. The scantlings of the collision bulkhead are to be in accordance with *Pt 3, Ch 5, 6.5 Collision bulkhead*. Where bulkhead stiffeners support deck girders, transverses or pillars over, they are also to comply with *Table 7.2.3 Bulkhead stiffeners supporting concentrated loads*.

2.1.2 Stiffening members of horizontal bulkheads of tanks may be supported by girders or a system of girders and pillars.

Table 7.2.1 Watertight and deep tank bulkhead scantlings

Item and requirement	Watertight bulkheads	Deep tank bulkheads
(1) Plating thickness for plane and symmetrically corrugated bulkheads	The greater of the following: $t = 4w\sqrt{h_4 k} + 0{,}5$ mm or t = 4 mm, *see* Note 3	The greater of the following: $t = 4w\sqrt{\rho h_4 k} + a$ mm or t = 5 mm for oil tanks and fresh water tanks t = 5,5 mm for water ballast tanks, *see* Note 3
(2) Modulus of rolled and built stiffeners, swedges and symmetrical corrugations	$Z = 5 \times k \times s \times l_e^{\,2} \times h_4$ cm^3	$Z = 6 \times k \times s \times l_e^{\,2} \times h_4 \times \rho$ cm^3
(3) Stringers or webs supporting vertical or horizontal stiffening (a) Modulus (b) Inertia	$Z = 7 \times k \times h_4 \times S \times l_e^{\,2}$ cm^3 -	$Z = 8{,}5 \times k \times h_4 \times S \times l_e^{\,2} \times \rho$ cm^3 $= I = \frac{2,5}{k} \times Z \times l_e$ cm^4
(4) Pillars in tanks, cross-sectional area	-	$A = 4{,}5 + 0{,}9P$ cm^2
Symbols		

t = thickness of plating, in mm

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

s = spacing of stiffeners, corrugations, girders or webs, in metres

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

ρ = specific gravity of liquid carried in the tank, but is to be taken as not less than 1

w = plate width, in metres, defined as follows:

= (a) for plane bulkheads the spacing of stiffeners, in metres

= (b) for corrugated bulkheads the width of flange (b) or web (c), in metres, whichever is the greater, *see Figure 3.3.3 Dimensions and symbols for corrugated bulkheads* in Ch 3,3

a = 1 mm for oil and fresh water tanks and 1,5 mm for water ballast tanks

h_4 = load head, in metres, measured vertically as follows, *see also Figure 7.2.1 Heads for watertight and deep tank bulkheads*

(a) for vertically stiffened watertight bulkhead plating – the distance from a point 0,5 m above the lower edge of the plate to the top of the bulkhead

(b) for horizontally stiffened watertight bulkhead plating - the distance from the middle of the first panel above the lower edge of the plate to the top of the bulkhead

(c) for vertically stiffened deep tank bulkhead plating - the distance from a point 0,5 m above the lower edge of the plate to a point 1 m above the top of the tank, or to the top of the overflow, whichever is the greater

(d) for horizontally stiffened deep tank bulkhead plating - the distance from the middle of the first panel above the lower edge of the plate to a point 1 m above the top of the tank, or to the top of the overflow, whichever is the greater

(e) for watertight stiffeners or girders, the distance from the middle of the effective length to the top of the bulkhead

(f) for deep tank bulkhead stiffeners or girders, the distance from the middle of the effective length to a point 1 m above the top of the tank, or to the top of the overflow, whichever is the greater

P = load supported by the pillars, in tonne f

Note 1. For rolled or built stiffeners with flanges for face plates the web thickness is to be not less than $\frac{1}{60}$ of the web depth, whilst for flat bar stiffeners the web thickness is to be not less than $\frac{1}{16}$ of the web depth.

Note 2. Additional requirements for corrugated bulkheads are given in *Pt 3, Ch 3, 3.2 Geometric properties of section*.

Note 3. Bulkhead plating from the bottom to 0,1 m above ceiling in holds is to be at least 6 mm in thickness.

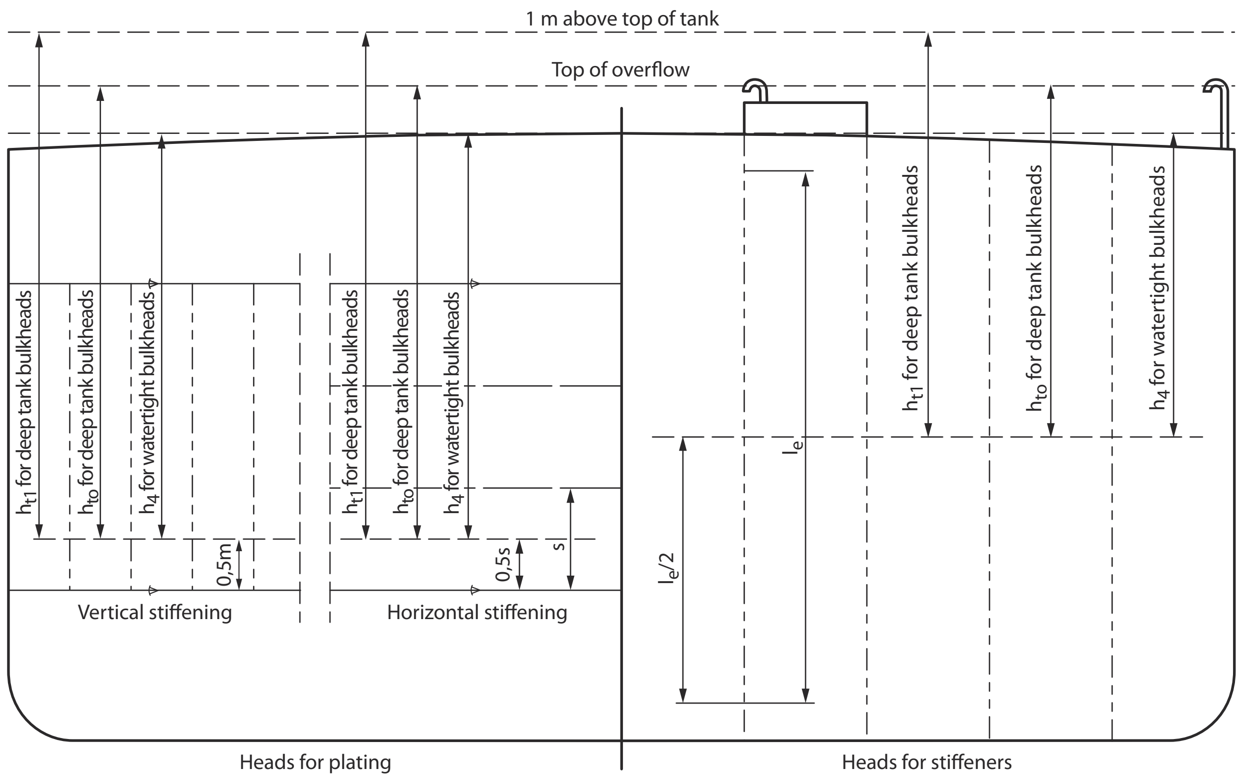


Figure 7.2.1 Heads for watertight and deep tank bulkheads

2.1.3 Pillars in tanks are not to be of hollow construction and are to be bracketed at top and bottom. Scantlings and welding of the brackets are to take account of the maximum tensile force on the pillar.

2.1.4 End connections of stiffeners are to be in accordance with the requirements of *Pt 3, Ch 10, 3 Secondary member end connections*. Where stiffeners are not fitted with the required end brackets, the modulus of the stiffeners is to be increased in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

2.1.5 Fuel oil carried in tanks is to have a flash point not less than 55°C. Where tanks are intended for liquid fuels of a special nature, the scantlings and arrangements will be considered in relation to the nature of the fuel, *see also Pt 3, Ch 12, 2 Rudders*.

2.1.6 If cargo is carried in a compartment adjacent to a fuel oil tank which may be heated, the compartment side of the bulkhead or deck is to be insulated, or equivalent arrangements provided.

2.1.7 Where watertight bulkhead stiffeners are cut in way of watertight doors, the opening is to be suitably framed and reinforced, and the adjacent stiffeners are to be increased in proportion to the greater spacing. Where the stiffener spacing is locally increased on account of watertight doors, the stiffeners at the sides of the doorways are also to be increased. Recesses in bulkheads are generally to be so stiffened as to provide strength and stiffness equivalent to the requirements for the bulkhead.

2.2 Non-watertight bulkheads

2.2.1 The scantlings of non-watertight bulkheads acting as hull supporting structure are to comply with the requirements of *Table 7.2.2 Non-watertight bulkheads*. Where the bulkhead stiffeners support deck girders, transverses or pillars over, they are also to comply with the requirements of *Table 7.2.3 Bulkhead stiffeners supporting concentrated loads*.

Table 7.2.2 Non-watertight bulkheads

Parameter	Requirements
(1) Plating thickness for plane bulkheads	The greater of the following: $t = 4 \times k \times s \times \sqrt{h_4}$ mm or t = 3,5 mm
(2) Modulus of rolled and built stiffeners and swedges	$Z = 4 \times k \times s \times l_e{}^2 \times h_4 + 3$ cm^3
Note *See Table 7.2.3 Bulkhead stiffeners supporting concentrated loads* for symbols definition.	

Table 7.2.3 Bulkhead stiffeners supporting concentrated loads

Parameter	Requirements
(1) Cross-sectional area for rolled, built or swedged stiffeners, supporting girders, transverses, pillars or concentrated loads	$A = \dfrac{K + P}{1,26 - 4,2\dfrac{l}{r\sqrt{k}}}$ cm^2 *see* Note
(2) Width of effective plating included in the cross-sectional area	The lesser of the following w = 80t mm or w = 700s mm

Symbols

h_4 = load, head, in metres, as specified for watertight bulkheads in *Table 7.2.1 Watertight and deep tank bulkhead scantlings*

l = overall length of stiffener, in metres, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

r = least radius of gyration of stiffener with effective plating, in mm, and is to be taken as:

$$10\sqrt{\frac{I_p}{A}}$$

s = spacing of stiffeners, in metres, but not to exceed 1,10 m

t = thickness of plating, in mm

w = width of effective plating, in mm

A = cross-sectional area of stiffening member inclusive of effective plating, in cm^2

I_p = least moment of inertia of stiffener with effective plating, in cm^4

P = load supported by stiffener, in tonne-f

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

Note The depth of stiffeners supporting concentrated loads is to be not less than 75 mm.

2.3 Bulkheads in cargo spaces

2.3.1 Bulkheads in cargo holds which are regularly exposed to contact with grabs or falling cargo are to be efficiently protected or the scantlings increased in order to reduce damage.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ships.

1.1.2 The scantlings of superstructures, deck-houses and exposed machinery casings are generally to comply with the following requirements, but increased scantlings may be required where the structure is subjected to loading in excess of Rule limits, *see Pt 3, Ch 3 Structural Design*.

1.1.3 The term 'erection' is used in this Section to include superstructures, deck-houses and machinery casings, superstructures being erections extending to the ship's sides.

1.1.4 For scantlings of protected machinery casings, *see Pt 3, Ch 6, 6 Machinery casings and fuel oil tanks*.

1.1.5 For requirements relating to companionways, doors, accesses and skylights, *see Pt 3, Ch 11 Closing Arrangements to Openings in Shell and Deck, Ventilators, Air Pipes, Sounding Pipes and Discharges*.

1.2 Definition of tiers

1.2.1 The lowest, or first tier, is that which is directly situated on the deck to which the depth, *D*, is measured or on a superstructure of less than 1,80 m in height. The second tier is the next tier above the lowest tier and so on.

■ *Section 2* Scantlings of erections

2.1 Superstructures

2.1.1 The scantlings of plating and framing and the type of end connections of the side structure are to be the same as for the shell in way.

2.1.2 The scantlings of plating and stiffening and the type of end connections of the end bulkheads are to be the same as for the end bulkheads of deck-houses, *see Table 8.2.1 Deckhouse scantlings* (and further references as per *Pt 3, Ch 8, 2.2 Deck-houses and exposed machinery casings bulkhead plating 2.2.1*, *Pt 3, Ch 8, 2.3 Stiffeners and their end connections 2.3.2*, *Pt 3, Ch 8, 2.4 Deck plating 2.4.1* and *Pt 3, Ch 8, 2.6 Deck supporting structure 2.6.2*).

Table 8.2.1 Deckhouse scantlings

Item	Parameter	Requirements
Side and end bulkheads of lower tier	Plating: $t = 7{,}5s + 0{,}010L$ mm	Stiffeners: $Z = 14fs + 4$ cm^3 wherein $f = 1{,}25 - 0{,}005L$ *See* Notes 1 and 2
Side and end bulkheads of 2nd and 3rd tiers	Plating:The greater of: $t = 7{,}5s + 0{,}010L - 0{,}75$ mm $t = 3$ mm	Stiffeners: $Z = 14fs + 4$ cm^3 wherein $f = 1{,}25 - 0{,}005L$ *See* Notes 1 and 3
Decks (all tiers)	Plating: $t = 8{,}0s + 0{,}013L$ mm	Beams and longitudinals: $Z = 4s\,h_i l_b^{\,2} + 4$ cm^3 *See* Note 4
	Non-exposed decks and top decks: $t = 8{,}0s$ mm	Girders and transverses: $Z = 4{,}5h_i S l_e^{\,2} + 4$ cm^3 $I = 2{,}3 l_e Z$ cm^4
Pillars, *see* Note 5	Cross-sectional area	$A_p = 4{,}5 + 0{,}875P$ cm^2
	Minimum wall thickness of hollow pillars	The greater of: (a) $t = 0{,}033d_b$ mm for tubular pillars $= 0{,}056b$ mm for square pillars (b) $t = 5$ mm
Symbols		

b =	breadth of side of hollow square pillars, in mm
b_d =	breadth or length of the deck panel supported, in metres
d_b =	mean diameter of tubular pillars, in mm
f =	factor
h_i =	design head and is to be taken as 0,45 m for no load-bearing weather and accommodation decks and 0,30 m for top decks and the relevant values for h_i from *Table 3.4.1 Design heads and permissible cargo loading (SI units)* for load-bearing decks
l_b =	span, in metres, of deck beam or longitudinals and is to be taken not less than 1,5 m
l_e =	effective span, in metres, of girder or transverse as defined in *Pt 3, Ch 3, 3.3 Determination of span point*
s =	spacing of stiffeners, beams or longitudinals, in metres
A_p =	cross-sectional area of tubular or hollow square pillar, in cm^2
L =	length of ship, in metres, as defined in *Pt 3, Ch 1, 6.1 Principal particulars*
P =	load, in tonne-f, supported by the pillar and is to be taken as $P = 0{,}72Sb_d h_i$ tonne-f, to which the load exerted by superposed pillars is to be added
S =	spacing or mean spacing of girders, transverses or pillars supporting them, in metres
t =	thickness of plating, in mm
Z =	section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

Note 1. If the unsupported length of a stiffener exceeds 2,5 m the section modulus is to be suitably increased.

Note 2. The section modulus of the stiffeners is to be increased by 15 per cent where a second tier house is fitted and by 30 per cent where also a third tier is fitted.

Note 3. The section modulus of the stiffeners of the second tier is to be increased by 15 per cent if a third tier house is fitted.

Note 4. The depth of beams and longitudinals is to be not less than 45 mm.

Note 5. The minimum diameter of hollow pillars is 50 mm. The minimum dimensions of hollow square pillars is 45 x 45 mm. Solid and fabricated pillars are to be of equivalent strength.

2.1.3 The scantlings of plating and stiffening and the type of end connections of the deck structure are to be the same as for the main deck in the respective position.

2.2 Deck-houses and exposed machinery casings bulkhead plating

2.2.1 The thickness, t, of exposed end and side bulkheads is to comply with the requirements of *Table 8.2.1 Deckhouse scantlings*.

2.2.2 The thickness of load-bearing internal bulkheads is to be not less than 3 mm in conjunction with suitable stiffening.

2.3 Stiffeners and their end connections

2.3.1 Stiffeners are to be fitted in line with deck beams or longitudinals.

2.3.2 The section modulus of stiffeners of end and side bulkheads is to be in accordance with *Table 8.2.1 Deckhouse scantlings*.

2.3.3 The lower end of stiffeners of single tier deckhouses may be unattached. The upper end of stiffeners of all tiers is to be connected to the deck beams or longitudinals.

2.3.4 When a multiple tier erection is fitted, the lower end of the side bulkhead stiffeners is to be attached to the deck, except in the case of the uppermost tier.

2.4 Deck plating

2.4.1 The thickness of exposed and unexposed deck plating is to be in accordance with *Table 8.2.1 Deckhouse scantlings*.

2.5 Deck stiffening

2.5.1 Deck beams and longitudinals are to have a section modulus in accordance with the requirements of *Table 8.2.1 Deckhouse scantlings*.

2.5.2 The beams and longitudinals are to be connected to the bulkhead stiffeners.

2.6 Deck supporting structure

2.6.1 Decks are to be supported by suitably spaced girders or transverses and pillars.

2.6.2 The scantlings of girders, transverses and pillars are to comply with *Table 8.2.1 Deckhouse scantlings*.

2.6.3 Effective support is to be fitted under the heel of pillars.

2.6.4 The girders and transverses are to be suitably connected to the bulkhead stiffening. The modulus of the bulkhead stiffeners bearing transverses is to be increased by 40 per cent. End connections are generally to comply with *Pt 3, Ch 10, 4.7 End connections*.

2.7 Strengthening at sides and ends of erections

2.7.1 Web stiffeners or equivalent strengthening is to be arranged to support the sides of large erections.

2.7.2 Web stiffeners should be spaced about 10 m apart and are to be arranged in line with bulkheads or webs below.

2.7.3 Web stiffeners or equivalent strengthening is also to be fitted within erections that have erections above exceeding 5 m in length or, 0,1*L*, whichever is the greater.

2.7.4 Adequate support under the ends of erections is to be provided.

2.8 Erections in way of machinery spaces

2.8.1 If engines of high horsepower in relation to the size or type of ship are fitted, measures are to be taken to prevent undue vibration of the structure.

2.9 Erections contributing to hull strength

2.9.1 Where an effective superstructure, *see Pt 3, Ch 3, 3.4 Calculation of hull section modulus 3.4.2* or a deck-house with a length of more than 0,2*L* is fitted and which is situated within the midship 0,5*L* region, the scantlings of deck plating and longitudinals of these erections may require to be increased.

■ *Section 3*
Aluminium erections

3.1 Restrictions in application

3.1.1 Attention is drawn to the fact that National and International Statutory Requirements restrict the application of aluminium for certain types of ships.

3.2 Scantlings

3.2.1 Where an aluminium alloy complying with *Ch 8 Aluminium Alloys* of LR's Rules for Materials is used in the construction of erections, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in *Table 8.3.1 Percentage increase of scantlings*.

Table 8.3.1 Percentage increase of scantlings

Item	Percentage increase
Fronts, sides, aft ends, unsheathed deck plating	20
Decks sheathed in accordance with *Pt 3, Ch 2, 3 Deck covering*	10
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

3.2.2 The thickness, t, of aluminium alloy members is to be not less than:

t = $2,5 + 0,022d_{\mathrm{w}}$ mm, but need not exceed 10 mm

= where

d_{w} = depth of section, in mm.

3.2.3 The minimum moment of inertia, I, of aluminium alloy stiffening members is to be not less than:

I = $5,25Z\,l_1$ cm^4

= where

l_1 = the span of the member, in metres, and Z is the required section modulus of the steel stiffening member obtained from *Pt 3, Ch 8, 2 Scantlings of erections*.

3.3 Bimetallic joints

3.3.1 Where aluminium erections are arranged above a steel hull, details or the arrangements in way of the bimetallic connections are to be submitted.

■ *Section 4*
Bulwarks and other means for the protection of crew and passengers

4.1 General requirements

4.1.1 All ships having accommodation are to be fitted with a bulwark from the stem to the forward end of the foremost hatchway, forward cargo tank on tankers, and from the stern to the forward end of the aft deck-house. The height of forward bulwarks is to be not less than 500 mm and that for aft bulwarks not less than 450 mm. In way of deck-house doors the bulwark height is to be locally increased to 900 mm, this may be effected by fitting a rail on top of the bulwark.

4.1.2 Plate bulwarks may be replaced by guard rails or by a combination of a bulwark with guard rails on top, except forward where a plate bulwark is required.

4.1.3 Where bulwarks are fitted in the midship region, adequate freeing arrangements are to be provided.

4.2 Requirements for various ship types

4.2.1 In addition to *Pt 3, Ch 8, 4.1 General requirements 4.1.1*, all open deck spaces on passenger ships, to which passengers have access, are to be fitted with bulwarks or guard rails, having a minimum height of 900 mm. The opening below the lowest course of rails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart.

4.2.2 In addition to *Pt 3, Ch 8, 4.1 General requirements 4.1.1*, tankers are to be provided with guard rails of at least 900 mm high over the full length of the cargo zone. On trunk deck tankers the guard rails are to be fitted on the topside of the trunk. The guard rails should have at least two courses, the lower one fitted at approximately half height, i.e. about 450 mm above deck.

4.2.3 Other types of ships are to be fitted with bulwarks and/or guard/handrails, suitable for the type of ship and the service requirements. Bulwarks on push barges may be omitted.

4.2.4 Attention is drawn to National or International requirements by which the fitting of additional foot rails or handrails may be required.

4.3 Bulwark and guard rail construction

4.3.1 Plate bulwarks are to be efficiently supported by stays attached to the deck. These stays are to be fitted in way of beams or equivalent under deck stiffening and are not to be spaced more than 2,0 m apart. Guard rail supports are not to be spaced more than 3,0 m apart.

The bulwark thickness is to be not less than:

$$t = 4 + 0{,}015\,(L - 40)\text{ mm}$$

L is to be taken not less than 40 m

4.4 Means of escape

4.4.1 In accommodation spaces two means of escape are generally to be provided.

4.4.2 For means of escape from passenger spaces on passenger ships, *see Pt 4, Ch 9, 1.7 Ship arrangement – Means of escape, corridors and escape routes*.

■ *Section 1* General

1.1 Application

1.1.1 Requirements are given:

(a) For decks on which wheeled vehicles are to be used;
(b) For the strengthening of ships intended for navigation in ice.

1.1.2 The requirements of this Chapter are to be taken in conjunction with the Chapters of *Pt 3 Ship Structures (General)* and *Pt 4 Ship Structures (Ship Types)* applicable to the particular ship type.

■ *Section 2* Decks loaded by wheeled vehicles

2.1 General

2.1.1 Where it is proposed either to stow wheeled vehicles on the deck or to use wheeled vehicles for cargo handling, the deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a deck in this location.

2.2 Loading

2.2.1 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Shipbuilder. These details are to include the wheel load, axle and wheel spacing, tyre print dimensions and type of tyre for the vehicles.

2.2.2 For design purposes where wheeled vehicles are to be used for cargo handling, the deck is to be taken as loaded with a normal head of cargo, except in way of the vehicle.

2.3 Deck plating

2.3.1 The deck plating thickness is to comply with *Table 9.2.1 Loading by wheeled vehicles*.

Table 9.2.1 Loading by wheeled vehicles

Item	Parameter	Requirements
(1) Deck plating	Plating thickness	$t = \frac{\alpha s}{\sqrt{k}} + 1{,}5$ mm, *see* Note
(2) Deck beams, longitudinals and stiffeners when fork lift trucks are to be used	Section modulus	$Z = (0{,}375K_1 P l_e + 1{,}25K_2 h s l_e^2) k$ cm^3
(3) Deck beams, longitudinals and stiffeners for decks permanently used for vehicles, in association with a value of *h* which need not exceed 2,5 m	Section modulus	$Z = (0{,}536K_1 P l_e + 1{,}25K_2 h s l_e^2) k$ cm^3
(4) Deck girders and transverses	Section modulus	$Z = 4{,}75 b h l_e^2 k$ cm^3
Symbols		
b = mean width of plating supported by a deck girder or transverse, in metres h = normal load height on the deck, in metres, *see Pt 3, Ch 3, 4 Design loading* l_e = effective length, in metres, of the beam between span points, *see also Pt 3, Ch 3, 3.3 Determination of span point* s = spacing of stiffeners, in metres t = thickness of plating, in mm K_1 and K_2 are factors given in *Table 9.2.4 Values of K_1 and K_2* P = total weight of the vehicle divided by the number of axles. Where the distribution of weight is not uniform, P is to be taken as the maximum axle load. For fork lift trucks the total weight is to be applied to one axle, in tonnes P_1 = corrected patch load obtained from *Table 9.2.2 Corrected patch load calculation* in tonnes Z = section modulus of the member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section* α = thickness coefficient obtained from *Figure 9.2.1 Tyre print load stress factor* β = tyre print coefficient used in *Figure 9.2.1 Tyre print load stress factor* = $\log\left(\frac{P_1}{s^2} \times 10\right)$ k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*		
Note Where the necessary data of fork lift trucks are not initially available, the deck plate thickness may be estimated from the maximum beam spacing to plate thickness ratios *s/t* given in *Table 9.2.3 Approximate deck thickness for fork lift trucks*.		

Table 9.2.2 Corrected patch load calculation

Symbols	Expression	
a, s, u and *v* are as defined in *Figure 9.2.1 Tyre print load stress factor*	$P_1 = 1{,}25\Phi_1\Phi_2\Phi_3 P_w$	
P_1 = corrected patch load, in tonnes	$\Phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	$v_1 = v$, but $\leq s$ $u_1 = u$, but $\leq a$
Φ_1 = patch aspect ratio correction factor	$\Phi_2 = 1{,}0$	for $u \leq (a - s)$
Φ_2 = panel aspect ratio correction factor	$= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a-u)}$	for $a \geq u > (a - s)$
Φ_3 = wide patch load factor	$= 0{,}77\dfrac{a}{u}$	for $u > a$
P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in *Figure 9.2.1 Tyre print load stress factor* may be taken as the combined print	$\Phi_3 = 1{,}0$	for $v < s$
	$= 0{,}6\dfrac{s}{v} + 0{,}4$	for $1{,}5 > \dfrac{v}{s} > 1{,}0$
	$= 1{,}2\dfrac{s}{v}$	for $\dfrac{v}{s} \geq 1{,}5$

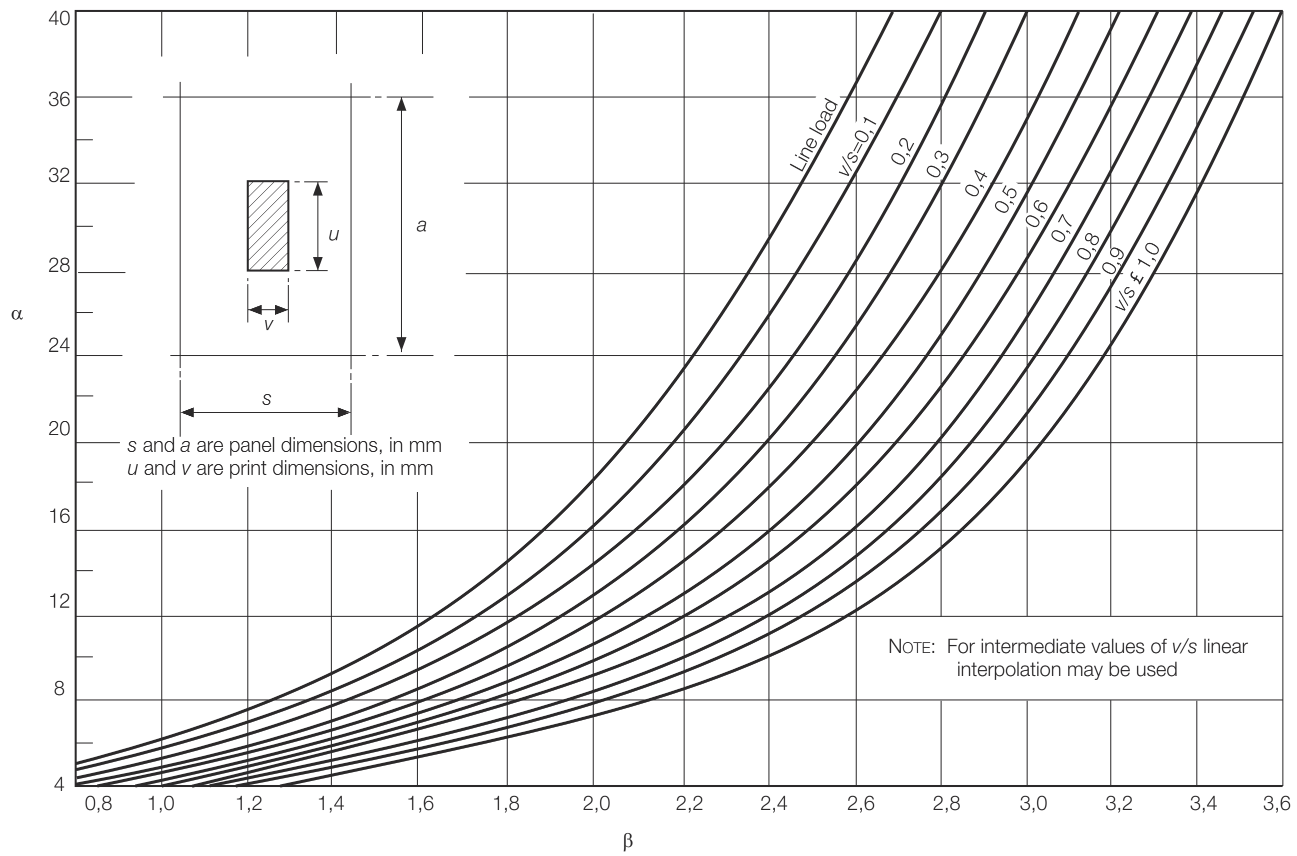


Figure 9.2.1 Tyre print load stress factor

Table 9.2.3 Approximate deck thickness for fork lift trucks

Capacity of fork lift, in tonnes	$\frac{s}{t}$ (max.)
1,0	0,085
5,0	0,045
10,0	0,037
15,0	0,034
20,0	0,032

Table 9.2.4 Values of K_1 and K_2

$\frac{\text{Wheel spacing*}}{\text{Beam Span}}$	K_1	K_2
0,1	15,4	1,89
0,2	14,6	1,845
0,3	13,35	1,730
0,4	11,8	1,55

0,5 and greater	10,1	1,30
*Outer wheel to outer wheel on axles with multiple wheel arrangements		

2.3.3 Where it is proposed to use vehicles having steel wheels, deck thicknesses will be specially considered.

2.3.4 Where transversely framed decks contribute to the hull girder strength or where secondary stiffening is fitted perpendicular to the direction of vehicle lanes, the thickness, t, derived from *Table 9.2.1 Loading by wheeled vehicles* is to be increased by 1,0 mm.

2.3.5 Where decks are designed for the exclusive carriage of unladen wheeled vehicles, the deck plate thickness, t, derived from *Table 9.2.1 Loading by wheeled vehicles* may be reduced by 0,75 mm.

2.3.6 Where it is proposed to carry tracked vehicles, the patch dimensions may be taken as the track print dimensions and P_w is to be taken as half the total weight of the vehicle. The deckplate thickness, t, derived from *Table 9.2.1 Loading by wheeled vehicles* is to be increased by 0,5 mm. Deck fittings in way of vehicle lanes are to be recessed.

2.3.7 If wheeled vehicles are to be used on insulated decks or tanktops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

2.4 Deck beams and longitudinals

2.4.1 The section modulus, Z, of deck beams or longitudinals is to be not less than that required for a deck in this location, nor less than the following:

(a) For general purpose cargo decks where fork lift trucks are to be used, the value of Z is to be as in *Table 9.2.1 Loading by wheeled vehicles*.
(b) For permanent vehicle decks in association with a value of h which need not exceed 2,5 m, Z is to be as in *Table 9.2.1 Loading by wheeled vehicles*.
(c) For decks designed for the carriage of wheeled vehicles only:

that required to satisfy the most severe arrangement of print wheel loads on the stiffener in association with a bending stress of 100 N/mm^2 (10,2 kgf/mm^2) assuming 100 per cent end fixity.

2.5 Deck girders and transverses

2.5.1 Where the load on deck girders and transverses is uniformly distributed the section modulus is to comply with *Table 9.2.1 Loading by wheeled vehicles*.

2.5.2 Where the member supports point loads, with or without the addition of uniformly distributed load, the section modulus is to be based on a stress of 123,6 N/mm^2 (12,6 kgf/mm^2) assuming 100 per cent end fixity.

2.5.3 Where it is proposed to carry tracked vehicles, the total weight of the vehicle is to be taken when determining the section modulus of the transverse at the top of a ramp or at other changes of gradient.

2.6 Heavy and special loads

2.6.1 Where heavy or special loads, such as machinery transporters or large tracked vehicles are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered.

■ *Section 3*
Strengthening for navigation in ice

3.1 General

3.1.1 This Section applies to all ships for which the class notation 'ICE' is desired. The class notation 'ICE' is intended for ships navigating in light ice conditions. The requirements of this Section are to be complied with in addition to the Rule requirements so far as applicable for the particular type of ship.

3.1.2 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations* to which reference should be made on the survey request form.

3.1.3 The requirements of this Section are applicable when transverse side shell framing is adopted. Special consideration will be given to proposals for longitudinal framing.

3.1.4 Ships specially designed for ice breaking duties will be individually considered.

3.2 Definitions

3.2.1 Ice belt is that part of the shell structure in the forward region which has to be reinforced. The longitudinal extent aft of this ice belt is the greater of the following:

(a) From the forward perpendicular to aft for a length equal to the breadth of the ship.
(b) From the forward perpendicular to aft where the ship reaches its greatest breadth plus 10 per cent of that distance.

The vertical extent of this ice belt is from 300 mm below the light waterline to 300 mm above the load waterline. Swim ends forward are part of the ice belt over their full vertical extent.

3.2.2 Light waterline is the lowest waterline, on which the ship is expected to navigate, taking account of trim.

3.2.3 Load waterline is the deepest waterline on which the ship is expected to navigate.

3.3 Shell plating and framing

3.3.1 The thickness of the shell plating in way of the ice belt is to be as required by *Table 9.3.1 Ice strengthening*.

Table 9.3.1 Ice strengthening

Item	Parameter	Requirements
(1) Shell plating and swim end plating (in way of ice belt)	Plating thickness	$t_i = 1{,}5t_r$ mm
(2) Intermediate ice frames	Section modulus	$Z_i = 0{,}75Z_r$ cm^3
(3) Side stringer	Section modulus	$Z_s = 2Z_r$ cm^3
(4) Bar stem	Area	$A = 0{,}75L$ cm^2
(5) Plate stem	Thickness	The greater of: $t_s = 0{,}10L + 5$ mm $t_s = 12$ mm
(6) Rudder stock and pintles	Diameter	$\delta_i = 1{,}15\delta_r$ mm, *see* Note
(7) Rudder plating and webs	Thickness	$t_w = 1{,}25t_{rs}$ mm
(8) Solepiece	Transverse section modulus	$Z_{sp} = 1{,}15Z_{rs}$ cm^3
Symbols		

t_{i}	=	thickness of shell plating in way of ice belt, in mm
t_{r}	=	Rule thickness of shell plating, or swim end plating, in mm
t_{rs}	=	Rule thickness of rudder plating or web plating, in mm
t_{s}	=	thickness of plate stem in way of ice belt, in mm
t_{w}	=	thickness of rudder plating or web plating, increased for navigation in ice, in mm
A	=	area of bar stem in way of ice belt, in cm^2
L	=	length of ship, in metres, *see Pt 3, Ch 1, 6.1 Principal particulars*
Z_{i}	=	section modulus of intermediate ice frames, in cm^3
Z_{r}	=	section modulus of the Rule main frames, in cm^3
Z_{rs}	=	Rule transverse section modulus of solepiece, in cm^3
Z_{s}	=	section modulus of side stringer in way of ice belt, in cm^3
Z_{sp}	=	transverse section modulus of solepiece increased for navigation in ice, in cm^3
δ_{i}	=	diameter of rudder stock or pintle increased for navigation in ice, in mm
δ_{r}	=	Rule diameter of rudder stock or pintle, in mm

Note The gudgeons, rudder couplings and steering gear are to be based on the rudder stock diameter increased for navigation in ice.

3.3.2 Intermediate ice frames are to be fitted over the extent of the ice belt; and their scantlings are to comply with the requirements of *Table 9.3.1 Ice strengthening*. The ends of these frames may be sniped.

3.3.3 A side stringer is to be fitted over the longitudinal extent of the ice belt a position about half way between light and load waterlines and efficiently connected to frames and shell. The scantlings of this stringer are to be as required by *Table 9.3.1 Ice strengthening*.

3.4 Stem

3.4.1 A bar stem or plate stem is to comply with *Table 9.3.1 Ice strengthening*. Bar and plate stems, and their adjoining shell plating, are to be supported by horizontal webs, with a thickness equal to the shell plating in way, connected to the first frame, and spaced not more than 0,5 m apart. Furthermore, a centreline stiffener is required inside a plate stem. This centreline stiffener may be of the same scantlings as the fore peak frames.

3.5 Rudder and sternframe

3.5.1 The rudder stock diameter, pintle diameter and rudder plating and webs are to be as required by *Table 9.3.1 Ice strengthening*. The gudgeons, coupling, main piece and steering gear are to be based on the increased diameter of the rudder stock required for navigation in ice.

3.5.2 The solepiece section modulus for transverse bending is to be as required by *Table 9.3.1 Ice strengthening*.

■ *Section 4*
Lifting appliances and associated support arrangements

4.1 Lifting appliances and associated pedestals

4.1.1 It is the responsibility of the designer to ensure that the ship is suitable for the intended lifting appliance operations. Particular attention is drawn to ships or units which have heavy lift cranes (or lifting appliances) installed (*see Ch 4, 1.2 Lifting appliances and crane types 1.2.1.(k)* of the *Code for Lifting Appliances in a Marine Environment, July 2022*).

4.1.2 Lifting appliance pedestals or foundations are to be designed with respect to the worst possible combinations of loads resulting from the crane self-weight, live load, wind and crane accelerations together with those resulting from the vessel's heel and trim.

4.1.3 Stowage arrangements are to be taken into account when calculating the loads to be applied to the pedestal.

4.1.4 When submitting plans for the proposed pedestal or foundation, the designer is to include design calculations covering the parameters indicated in *Pt 3, Ch 9, 4.1 Lifting appliances and associated pedestals 4.1.2* and *Pt 3, Ch 9, 4.1 Lifting appliances and associated pedestals 4.1.5*.

4.1.5 The maximum permissible bending stress is given by:

$$\sigma_a = 0{,}58\sigma_o \text{ N/mm}^2$$

Where:

σ_o = specified minimum yield stress in N/mm^2

4.1.6 The maximum permissible shear stress is given by:

$$\tau_a = 0{,}58\frac{\sigma_o}{\sqrt{3}} \text{ N/mm}^2$$

Where:

σ_o = specified minimum yield stress in N/mm^2

4.2 Support structure for lifting appliance pedestals

4.2.1 Lifting appliance pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, lifting appliance pedestals can comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

4.2.2 The deck plating and underdeck stiffening in way of a lifting appliance pedestal is to be assessed using the same criteria used to assess the lifting appliance pedestal.

4.2.3 Insert plates are to be incorporated in the deck plating in way of lifting appliance foundations. The thickness of the insert plates is to be as required by the designer's calculations but in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

4.2.4 Where fitted, all inserts are to have well radiused corners and be suitably edge prepared prior to welding. The connection between the insert plate and the adjacent deck plating is to be full penetration. All other welding in way of the insert plate is generally to be double continuous and full penetration in way of critical locations. Tapers are to be not less than three to one.

4.3 Support structure for ramps

4.3.1 The support structure (including hinges) in way of the interface between a ramp and the ship is to be assessed in accordance with the appropriate criteria given in *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a Marine Environment, July 2022*.

4.3.2 The loads that the ramp supporting structure will be subjected to are to be submitted by the designer or Shipbuilder. These loads are to be calculated in accordance with *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a*

Marine Environment, July 2022. Load cases calculated in accordance with alternative standards can be accepted subject to agreement with Lloyd's Register.

4.3.3 Loads already existing in the supporting structure (other than those from the ramp) are to be superimposed if applicable.

4.3.4 Ramps forming part of the watertight integrity of the hull are also to be assessed in accordance with the applicable scantling requirements.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components.

1.1.2 Requirements are given in this Chapter for the following:

(a) Weld scantlings, weld procedures, workmanship and weld details.
(b) End connection scantlings and constructional details for stiffening members.
(c) Primary member proportions, stiffening and construction details.

1.2 Symbols

1.2.1 Symbols are defined as necessary in each Section.

■ *Section 2* Welding

2.1 General

2.1.1 Details of the welded connections of main structural members, including type and size of welds, are to be clearly indicated on the plans submitted for approval. This includes welded connections to steel castings. The extent to which automatic welding is used should be indicated.

2.1.2 Unless otherwise indicated, all welding is to be in accordance with the requirements of *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2 Fillet welds

2.2.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_{\text{p}} \text{ x weld factor x } \frac{d}{s}$$

where

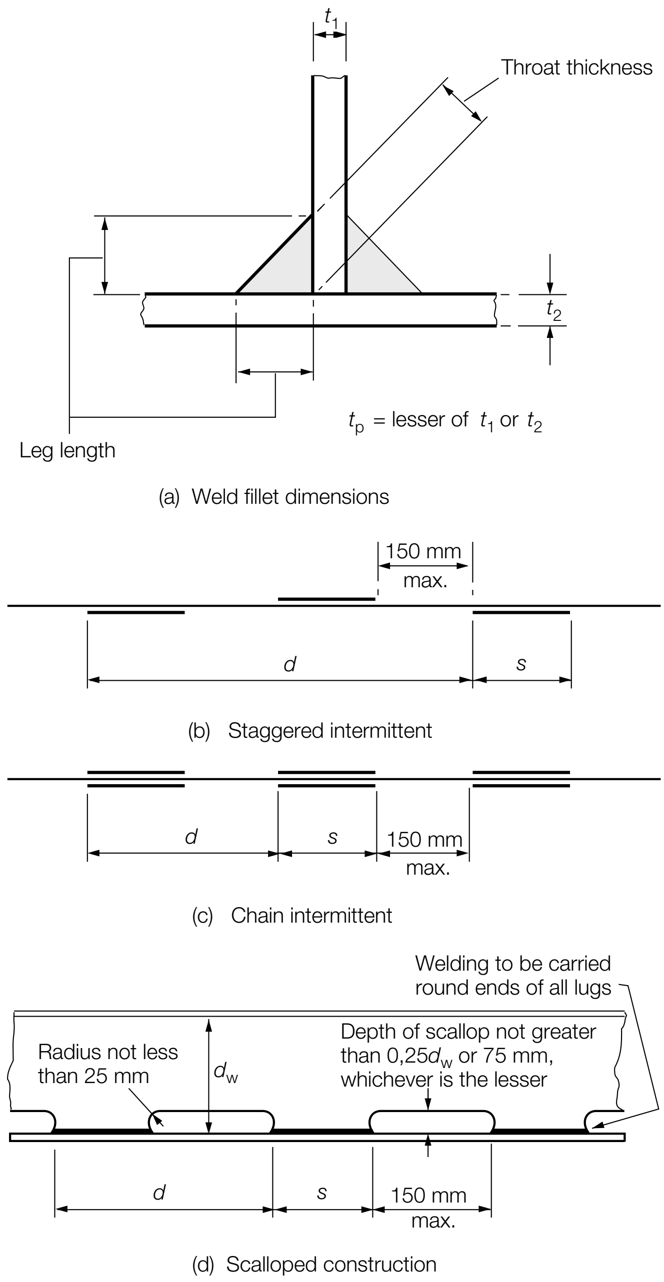
d = the distance between start positions of successive weld fillet, in mm

s = the length, in mm, of correctly proportioned weld fillet, clear of end craters, and is to be not less than 75 mm

t_p = plate thickness, on which weld fillet size is based, in mm

see also Figure 10.2.1 Weld types.

Weld factors are given in *Table 10.2.1 Weld factors* and *Table 10.2.2 Throat thickness limits*.



NOTE *s* to be not less than 75 mm, in all cases

Fig. 10.2.1 Weld types

Figure 10.2.1 Weld types

Table 10.2.1 Weld factors

	Item	Weld factor	Remarks
(1)	General application:		except as required below
	Watertight plate boundaries	0,34	
	Non-tight plate boundaries	0,13	
	Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	in tanks in way of end connections
	Panel stiffeners, etc.	0,10	
	Overlap welds generally	0,27	
(2)	Bottom construction in way of holds or tanks:		
	Non-tight centre girder : to keel	0,27	
	to inner bottom	0,21	no scallops
	Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
	Watertight bottom girders	0,34	
	Connection of girder to inner bottom in way of longitudinal bulkheads supported on inner bottom	0,44	
	Inner bottom longitudinals or reverse frames	0,13	under holds strengthened for heavy cargoes
	Connection of floors to inner bottom in way of plane bulkheads or corrugated and double plate bulkheads supported on inner bottom. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3)	Hull framing:		
	Webs of web frames and stringers:		
	to shell	0,16	
	to face plate	0,13	
	Tank side brackets to shell and inner bottom	0,34	
(4)	Decks and supporting structure:		
	Strength deck plating to shell		as shown in *Table 10.2.5 Weld connection of strength deck plating to sheerstrake* but alternative proposals will be considered
	Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
	Webs of cantilevers to deck and to shell in way of root bracket	0,44	

	Webs of cantilevers to face plate	0,21	
	Pillars: fabricated	0,10	
	end connections	0,34	
	end connections (tubular)	full penetration	*see* Note 1
	Girder web connections and brackets in way of pillar heads and heels	0,21	continuous
(5)	Bulkheads and tank construction:		
	Plane, double plate and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom and deck	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
	Boundary at bottom, bilge, inner bottom and deck	0,44	
	Secondary members where acting as pillars	0,13	
	Non-watertight pillar bulkhead boundaries	0,13	
	Perforated flats and wash bulkhead boundaries	0,10	
(6)	Structure in cargo tanks of tankers:		
	Bottom longitudinals to shell	0,21	
	Longitudinal of flat-bar type to plating		
	Connections between primary structural members	0,44	at bottom
		0,34	at deck
	Oiltight bulkhead boundaries:		
	longitudinal bulkhead	0,44	
	transverse bulkhead	0,44	at bottom
		0,34	at deck, sides and longitudinal bulkhead
	Vertical corrugations to an inner bottom	full penetration	*see* Note 2
	Non-tight bulkhead boundaries to plating	0,21	
(7)	Structure in machinery space:		
	Centre girder to keel and inner bottom	0,27	
	Floors to centre girder in way of engine, thrust and boiler bearers	0,27	
	Floors and girders to shell and inner bottom	0,21	
	Main engine foundation girders:		
	to top plate	deep penetration to	edge to be prepared with maximum root 0,33tp deep
	to hull structure	depend on design	penetration generally
	Floors to main engine foundation girders	0,27	

	Brackets, etc. to main engine foundation girders	0,21	
	Transverse and longitudinal framing to shell	0,13	
(8)	Fore peak construction:	all internal structure	0,13 unless a greater weld factor is required
(9)	After peak construction: All internal structure and stiffeners on after peak bulkhead	0,21	unless a greater weld factor is required
(10)	Superstructure and deckhouses:		
	Connection of external bulkheads to deck	0,34	1st and 2nd tier erections
		0,21	elsewhere
	Internal bulkheads	0,13	
(11)	Hatchways and closing arrangements:		
	Hatchways coamings to deck	0,34	
	Hatch cover rest bar	0,16	
	Hatch coaming stays to coaming	0,13	
	Hatch coaming stays to deck	0,21	
	Cleats and fittings	0,44	full penetration welding may be required
	Primary and secondary stiffening of hatch covers	0,10	0,13 for tank covers and where covers strengthened for loads over
(12)	Steering control systems:		
	Rudder:		
	Fabricated mainpiece and mainpiece to side plates and webs	0,44	
	Slot welds inside plates	0,44	
	Remaining construction	0,21	
	Fixed and steering nozzles:		
	Main structure	0,44	
	Elsewhere	0,21	
	Fabricated housing and structure of thruster units, stabilizers, etc:		
	Main structure	0,44	
	Elsewhere	0,21	
(13)	Miscellaneous fittings and equipment:		
	Rings for manhole type covers, to deck or bulkhead	0,34	
	Frames of shell and weathertight bulkhead doors	0,34	
	Stiffening of doors	0,21	
	Ventilator, air pipe, etc. coamings to deck	0,21	
	Ventilator, etc. fittings	0,21	

Scuppers and discharges, to deck	0,44	
Masts, derrick posts, crane pedestals, etc. to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration welding may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc. to deck	0,34	
Bilge keel ground bars to shell	0,34	Continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	Light continuous fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	
Note 1. Where pillars are fitted inside tanks or under watertight flats, the end connection is to be such that the tensile stress in the weld does not exceed 108 N/mm^2 (11 kgf/mm^2). Note 2. Up to a thickness of 10 mm double continuous fillet welding may be applied whereby a weld factor of 0,50 is to be used.		

2.2.2 Where an approved deep penetration procedure is used, the fillet leg length calculated from the weld factors given in the Tables may be reduced by 15 per cent provided that the Shipyard is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with *Ch 13 Requirements for Welded Construction* of the Rules for Materials for either the 'p' or 'T' techniques.

(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e. throat thicknesses) are maintained. This is to be documented on a monthly basis by the Shipyard, and made available to the Surveyor on request.

A reduction of 20 per cent may be given provided that in addition to the requirements of *Pt 3, Ch 10, 2.2 Fillet welds 2.2.2* and *Pt 3, Ch 10, 2.2 Fillet welds 2.2.2.(b)* the Shipyard is able consistently to meet the following additional requirements:

(a) The documentation required in *Pt 3, Ch 10, 2.2 Fillet welds 2.2.2.(b)*is to be completed and made available to the Surveyor upon request on a weekly basis.

(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.2.3 The leg length of the weld is to be not less than $\sqrt{2}$ x the specified throat thickness.

Table 10.2.2 Throat thickness limits

Item			Throat thickness, in mm	
			Minimum	Maximum
(1)	Double continuous welding		$0{,}21t_p$	$0{,}44t_p$
(2)	Intermittent welding		$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3)	All welds, overriding minimum:			
	(a)	Plate thickness $t_p \leq 7{,}5$ mm		
		Hand or automatic welding	3,0	—
		Automatic deep penetration welding	3,0	—
	(b)	Plate thickness $t_p > 7{,}5$ mm		
		Hand or automatic welding	3,25	—
		Automatic deep penetration welding	3,0	—

Note 1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above.

Note 2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to 0,4 (t_p + 25) mm.

Note 3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

2.2.4 The plate thickness, t_p, to be used in the above calculation is, generally, to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be considered.

2.2.5 Double continuous welding is to be adopted as required by section *Pt 3, Ch 10, 2.2 Fillet welds 2.2.7* and is recommended in the following locations:

(a) All welding inside tanks.
(b) All welding in chain lockers and other wet spaces.
(c) All welding exposed to the weather.

2.2.6 Except as prescribed by *Table 10.2.1 Weld factors* , for corrugated bulkheads, the throat thickness of the weld is not to be outside the limits specified in *Table 10.2.2 Throat thickness limits*.

2.2.7 Continuous welding is to be adopted in the following locations, and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings;
(b) Boundaries of tanks and watertight compartments;
(c) All structure in the after peak and the after peak bulkhead stiffeners;
(d) All welding inside tanks intended for chemicals or edible liquid cargoes;
(e) All lap welds in tanks;
(f) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections;
(g) Other connections or attachments, where considered necessary, and in particular the attachment of minor fittings to higher tensile steel plating;
(h) Fillet welds where higher tensile steel is used.

2.2.8 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at the orthogonal connections with other members.

2.2.9 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively, a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

2.3 Full penetration welding

2.3.1 Full penetration welding is to be adopted for all boundaries of the hull envelope plating below the sheerstrake (including shell penetrations) to the sea and as indicated in *Table 10.2.1 Weld factors* .

2.4 Doublers

2.4.1 When local doublers are used on the side shell plating to act as rubbing bars, full penetration welding of the butt welds is to be ensured and suitable ceramic backing bars or mineral fibre tapes are to be used for welding the butt welds to prevent actual attachment to the shell plating in way. The doublers are to be attached to the side shell plating with seam welding only after individual welding of the butt welds as described above. Doublers are not to be used in lieu of an inserted sheerstrake and are not to be included in the calculation of the hull section modulus.

2.5 Welding of primary and secondary member end connections

2.5.1 Weld factors for the connections of primary structure are given in *Table 10.2.3 Connections of primary structure*.

Table 10.2.3 Connections of primary structure

Primary member face area, in cm^2		Position[1]	Weld factor			
			In tanks		In dry spaces	
Exceeding	Not exceeding		To face plate	To plating	To face plate	To plating
	30,0	At ends	0,21	0,27	0,21	0,21
		Remainder.	0,10	0,16	0,10	0,13
30,0	65,0	At ends	0,21	0,34	0,21	0,21
		Remainder.	0,13	0,27	0,13	0,16
65,0	95,0	At ends	0,34	0,44[3]	0,21	0,27
		Remainder.	0,27[2]	0,34	0,16	0,21

Note 1. The weld factors ‘at ends’ are to be applied for 0,2 x the overall length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0,3 x overall length from the bottom.

Note 2. Weld factor 0,34 in cargo oil tanks.

Note 3. Where the web plate thickness is increased locally, the weld size may be based on the thickness clear of the increase, but is to be not less than 0,34 x the increased thickness.

Note 4. The final throat thickness of the weld fillet is to be not less than $0{,}34 t_p$ in cargo tanks of tankers.

2.5.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

2.5.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

2.5.4 The throat thickness limits given in *Table 10.2.2 Throat thickness limits* are to be complied with.

2.5.5 The welding of secondary member end connections is to be not less than as required by *Table 10.2.4 Secondary member end connection welds*.

Table 10.2.4 Secondary member end connection welds

	Connection	Weld area, A_w, in cm_2	Weld factor
(1)	Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2)	Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
	(a) in dry space	1,2 *Z*	0,27
	(b) in tank	1,4 Z	0,34
	(c) main frame to tank side bracket in 0,15*L* forward	as (a) or (b)	0,34
(3)	Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4)	Stiffener to plating for 0,1 x span at ends, or in way of end bracket if that is greater	—	0,34
Symbols			
	A_s = cross sectional area of the stiffener, in cm^2		
	A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm		
	Z = the section modulus, in cm^2, of the stiffener on which the scantlings of the bracket are based, *see Pt 3, Ch 10, 3 Secondary member end connections*		
Note For maximum and minimum weld fillet sizes, *see Table 10.2.2 Throat thickness limits*.			

2.5.6 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the welding area is to be at least 25 per cent greater than the cross-sectional area of the member.

2.6 Welding consumables and equipment

2.6.1 Welding consumables used and associated equipment is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

2.7 Welding procedures and welder qualifications

2.7.1 Welding procedures are to be established for the welding of all joints in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

2.7.2 All welding procedures are to be tested and qualified in accordance with the requirements of *Ch 12 Welding Qualifications* of the Rules for Materials and are to be approved by the Surveyor prior to construction.

2.7.3 Welders and welding operators are to be proficient in the type of work to be undertaken and are to be qualified in accordance with the requirements specified in *Ch 12 Welding Qualifications* of the Rules for Materials.

2.8 Inspection of welds

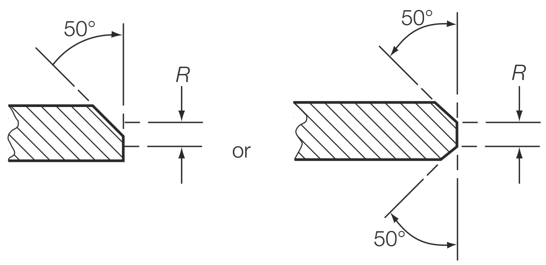
2.8.1 Effective arrangements are to be provided by the Builder for the inspection of finished welds to ensure that all welding has been satisfactorily completed, and provision and application of NDE shall comply with the general NDE requirements as per *Ch 1, 5.1 General NDE requirements* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

2.8.2 All finished welds are to be subjected to non-destructive examination in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*, and the general NDE requirements as per *Ch 1, 5.1 General NDE requirements* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

Table 10.2.5 Weld connection of strength deck plating to sheerstrake

Item	Stringer plate thickness, mm	Weld type
1	$t \leq 15$	Double continuous fillet weld with a weld factor of 0,44
2	$15 < t \leq 20$	Single vee preparation to provide included angle of 50° with root $R \leq {}^{1/3}\, t$ in conjunction with a continuous fillet weld having a weld factor of 0,39 or Double vee preparation to provide included angles of 50° with root $R \leq {}^{1/3}\, t$
3	$t > 20$	Double vee preparation to provide included angles of 50° with root $R \leq {}^{1/3}\, t$ but not to exceed 10 mm

Where t = thickness of stringer plate, in mm



Single vee preparation Double vee preparation

Note 1. Welding procedure, including joint preparation, is to be specified. Procedure is to be qualified and approved for individual Builders.

Note 2. *See also Pt 3, Ch 10, 2.2 Fillet welds 2.2.9*.

Note 3. For thickness t in excess of 20 mm the stringer plate may be bevelled to achieve a reduced thickness at the weld connection. The length of the bevel is in general to be based on a taper not exceeding 1 in 3 and the reduced thickness is in general to be not less than 0,65 times the thickness of stringer plate or 20 mm, whichever is the greater.

Note 4. Alternative connections will be considered.

2.9 Slot welding

2.9.1 The slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness or 20 mm, whichever is the greater. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm.

■ Section 3
Secondary member end connections

3.1 General

3.1.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section.

3.1.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member. For determination of span point,*see Pt 3, Ch 3, 3.3 Determination of span point*.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

Z = the section modulus of the stiffening member, in cm^3

a, b = the actual lengths, in mm, of the two arms of the bracket, measured from the plating to the toe of the bracket, *see Figure 10.3.1 Diagrammatic arrangements of stiffener end brackets*.

3.3 Basis for calculation of bracket connections

3.3.1 Scantlings of bracket connections are based on the following criteria:

(a) Where a bracket is connecting a stiffener to a primary member, the bracket is to be based on the modulus of the stiffener;
(b) Where a main transverse frame terminates, the bracket at the head of the frame is to be based on the modulus of the frame;
(c) Where, in the midship region, a longitudinal strength member is cut at a transverse supporting member and the continuity of strength is provided by brackets, the bracket is to be based on the cross-sectional area and the modulus of the longitudinal member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member;
(d) Elsewhere, the lesser modulus of the members being connected by the bracket.

3.4 Scantlings of end brackets

3.4.1 The lengths, *a* and *b*, of the arms are to be measured in accordance with *Figure 10.3.1 Diagrammatic arrangements of stiffener end brackets* and are to be such that:

(a) $a + b \geq 2{,}0l$
(b) $a \geq 0{,}8l$
(c) $b \geq 0{,}8l$

where

l is the length of a bracket as required by *Table 10.3.1 Bracket scantlings*.

3.4.2 Bracket scantlings are to comply with the requirements of *Table 10.3.1 Bracket scantlings*.

3.4.3 Where the bracket is lapped on to the stiffening member, the length and width of overlap is to be adequate to provide for the required area of welding, but the length of overlap should be not less than the depth of the stiffener.

3.4.4 For the purpose of these Rules, bracket connections not complying with these minimum requirements are considered as bracketless connections.

3.5 Arrangement and details

3.5.1 The modulus of the bracket through the throat is to be not less than that of the smaller stiffening member to be connected.

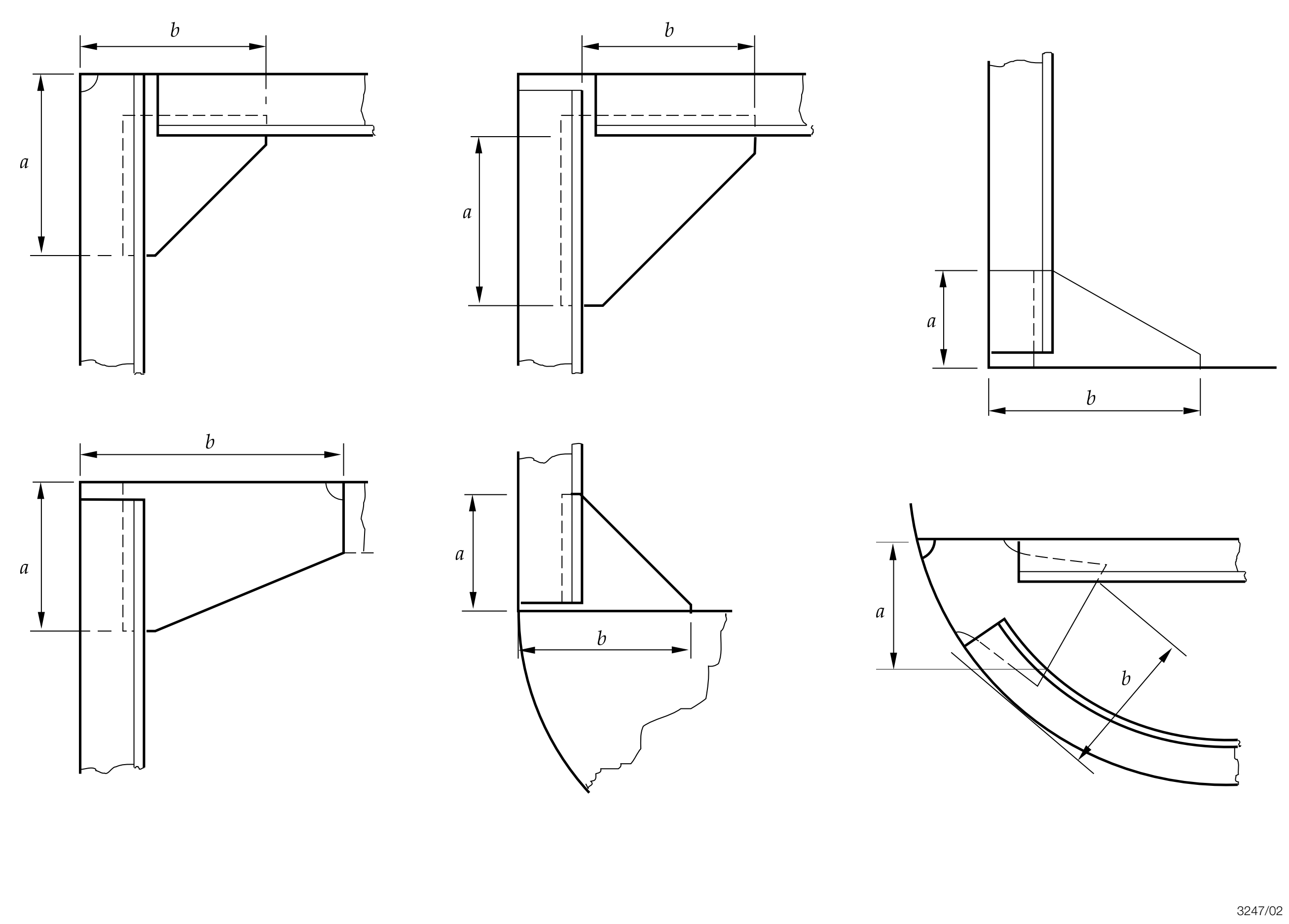


Figure 10.3.1 Diagrammatic arrangements of stiffener end brackets

Table 10.3.1 Bracket scantlings

Parameter	Requirement
Length of a bracket	The greater of the following: $l = 9\sqrt{Z} + 80 + d_s$ mm, or $l = 2d_s$ mm
Thickness of a bracket (a) unflanged	$t = 5 + 0,3\sqrt{Z}$ mm *see* Note
(b) flanged	The greater of the following: $t = 4 + 0,3\sqrt{Z}$ mm, or $t = 5$ mm
Flange width	$t = 50\left(1 + \frac{Z}{1000}\right)$ mm
Symbols	
b_f = breadth of the flange, in mm d_s = depth of the stiffening member, in mm l = arm length of bracket, in mm Z = as defined in *Pt 3, Ch 10, 3.2 Symbols 3.2.1*	
Note Where the length of the free edge of a bracket exceeds 50t mm, edge stiffening is to be fitted or the thickness is to be suitably increased.	

3.5.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

3.5.3 The toes of brackets should not land on unstiffened panels of plating. Special care should be taken to avoid notch effects at the toes of brackets.

3.6 Bracketless connections

3.6.1 For the purpose of these Rules, bracketless connections are divided into two types as follows:

Type 1:	Connections of stiffening members to each other, with a bracket connection as per *Figure 10.3.1 Diagrammatic arrangements of stiffener end brackets* or without a bracket, *see Figure 10.3.2 Types of bracketless end connections*
Type 2:	Stiffening members which are not connected at their ends, *see Figure 10.3.2 Types of bracketless end connections*.

3.6.2 Type 2 connections may only be adopted at watertight bulkhead stiffeners, wash bulkhead stiffeners and at stiffeners on centreline division bulkheads (non-tight) in tanks. Type 2 connections are not allowed for the secondary member end connections in way of the deep tank boundary or the shell boundary.

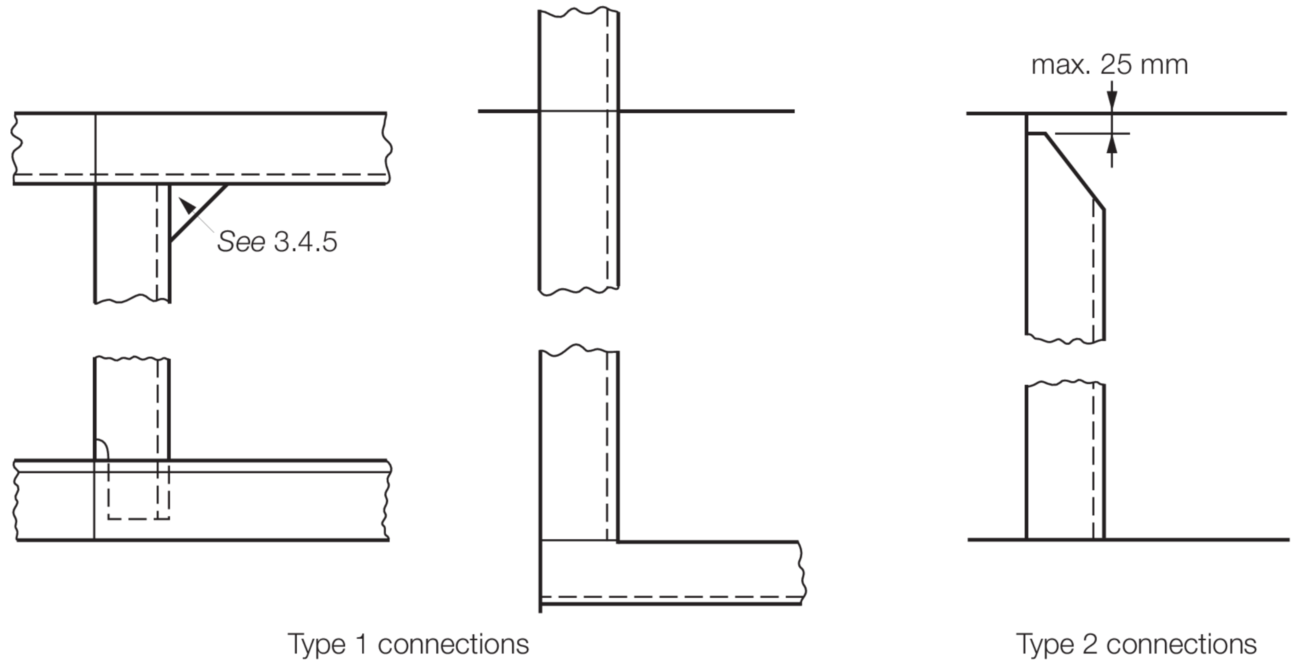


Figure 10.3.2 Types of bracketless end connections

3.7 Correction of stiffening member modulus in relation to end connections

3.7.1 Where a stiffening member is fitted with end brackets complying with, or in excess of the requirements of *Pt 3, Ch 10, 3.4 Scantlings of end brackets*, the modulus of the member need not be corrected.

3.7.2 The modulus of bracketless stiffeners is to be increased as follows:

Type 1 connection:	increase 10 per cent per end connection.
Type 2 connection:	increase 25 per cent per end connection.

3.8 End connections of corrugated bulkheads

3.8.1 The constraint of the end connection is to be assured by the positioning of floors and/or carlings or a corrugated bulkhead in line with the corrugated bulkhead under consideration. This type of connection is considered as a bracketless Type 1 connection, *see also Figure 10.3.3 End connections of corrugated bulkheads*. Where the bulkhead corrugations are not supported, the connection is considered as a Type 2 connection, *see also Figure 10.3.3 End connections of corrugated bulkheads*.

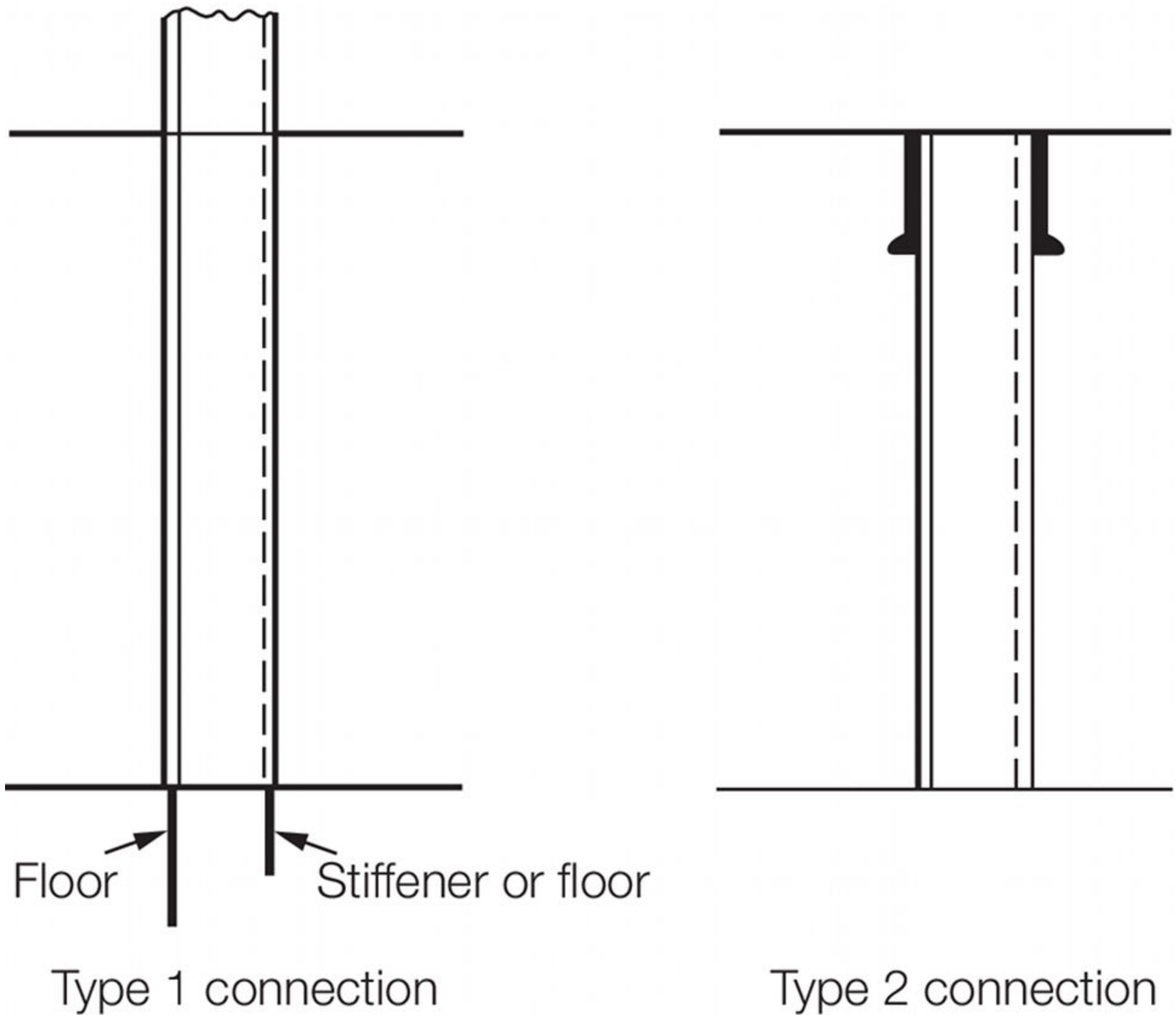


Figure 10.3.3 End connections of corrugated bulkheads

3.8.2 The yield stress of floors and/or carlings in line with the corrugated bulkhead is not to be less than the yield stress of the corrugated bulkhead.

■ *Section 4* Construction details for primary members

4.1 General

4.1.1 This Section includes the requirements for proportions, stiffening, end connections and construction details for primary members.

4.1.2 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

d_w = depth of member web, in mm

t_w = thickness of member web, in mm

A_f = area of member face plate or flange, in cm^2

S_w = depth of member web, or spacing of stiffeners on member web, whichever is the lesser, in mm

4.3 Arrangements

4.3.1 Primary members are to be so arranged as to ensure effective continuity of strength and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead or on other members, arrangements are to be made to ensure that they are in alignment. Primary transverse members in a longitudinal framing system are to form a continuous line of support and wherever possible, a complete ring system.

4.3.2 Where a primary member ends at a structure which provides only a low degree of restraint against rotation, the member is generally to extend for at least two frame spaces, or equivalent, beyond the point of support.

4.3.3 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

4.4 Geometric properties and proportions

4.4.1 The geometric properties of the member are to be calculated in association with an effective width of attached plating determined in accordance with *Pt 3, Ch 3, 3.2 Geometric properties of section*.

4.4.2 The minimum thickness or area of material in each component part of the primary member is given in *Table 10.4.1 Minimum thickness of primary structures*.

Table 10.4.1 Minimum thickness of primary structures

Item	Requirement
Member web plate, *see also Pt 3, Ch 10, 4.5 Web stability 4.5.4*	$t_w = 0{,}012 S_w$ mm but not less than 5 mm
Member face plate, *see* Note	A_f not to exceed $\dfrac{d_w t_w}{150}$ cm^2
Plating forming a flange of primary members	Plate thickness not less than $\sqrt{A_f}$ mm, for a width of plate not less than 750 mm
Symbols are as defined in *Pt 3, Ch 10, 4.2 Symbols 4.2.1*	
Note The member face plate area, A_f, may exceed this requirement, provided the lateral stability of the member is improved and the shear stress in the web plate does not exceed 83,4 N/mm^2 (8,5 kg/mm^2).	

4.5 Web stability

4.5.1 Primary members are to be supported by tripping brackets. The tripping brackets supporting asymmetrical sections are to be spaced no more than two secondary frames apart. The tripping brackets supporting symmetrical sections are to be spaced no more than four secondary frames apart.

4.5.2 Tripping brackets are also to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

4.5.3 Intermediate secondary members may be welded directly to the web or connected by lugs.

4.5.4 Apart from the requirements of *Table 10.4.1 Minimum thickness of primary structures*, the web thickness of a longitudinal girder at the strength deck within 0,5*L* amidships is to be not less than 0,018S_w mm.

4.6 Openings in the web

4.6.1 Where openings are cut in the web, the depth of opening is not to exceed 25 per cent of the web depth, and the opening is to be so located that the edges are not less than 40 per cent of the web depth from the face plate. The length of opening is not to exceed 60 per cent of the secondary member spacing. Where larger openings are proposed, the arrangement and compensation required will be considered. Openings are to have smooth edges and well rounded corners.

4.6.2 Cut-outs for the passage of secondary members are to have smooth edges and rounded corners and are to be kept as small as practicable. The connection of the web plating to the secondary member is to be sufficient for the load to be transmitted to the primary member.

4.7 End connections

4.7.1 End connections of primary members are generally to comply with the requirements of *Pt 3, Ch 10, 3 Secondary member end connections*, taking *Z* as the section modulus of the primary member.

4.7.2 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

4.7.3 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted.

4.7.4 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate resistance to rotation and displacement of the joint.

■ *Section 5*
Structural details

5.1 Continuity and alignment

5.1.1 Special attention is to be paid to structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

5.1.2 Where practicable, pillars and bulkheads should be placed in the same vertical line. Beam slots in girders, etc. in way of pillars, are to be collared.

5.2 Openings

5.2.1 Hatchways and other openings in strength and ‘tween decks are to have rounded corners.

5.2.2 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear stress. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams within one third of their length from either end, nor in floors or double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating are calculated and found acceptable.

5.2.3 Openings may require to be suitably framed and stiffened.

5.2.4 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges.

5.3 Fittings and attachments

5.3.1 Welding of fairlead stools, mouldings and other fittings to the top edge of the sheerstrake within 0,5*L* amidships, is to be avoided where possible. Bulwarks in this region should also be kept clear of the top edge of the sheerstrake, however, where welding on the top edge of the sheerstrake cannot be avoided, care is to be taken to minimise any notch effects.

5.3.2 Where a rounded gunwale is adopted, arrangements are to be made to ensure a smooth transition from rounded gunwale to angled gunwale.

5.3.3 Bilge keels, where fitted, are to be attached to a continuous ground bar, welded to the shell. The butts of bilge keels and ground bar should be completed before the bilge keels are welded to the shell. The ends of bilge keels are to be well sniped and arranged to land in way of an internal stiffener.

5.3.4 The quality of welding and general workmanship of fittings and attachments is to be equivalent to that of the main hull structure.

Closing Arrangements to Openings in Shell and Deck, Ventilators, Air Pipes, Sounding Pipes and Discharges

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in *Pt 4 Ship Structures (Ship Types)*. In addition to this Chapter, additional requirements for dry cargo ships carrying dangerous goods are given in *Pt 4, Ch 1 Dry Cargo Ships*. Additional requirements for tankers carring dangerous liquids in bulk are given in *Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*.

1.1.2 Requirements are given for:

(a) Steel, aluminium or wooden hatch covers, self-supporting and portable, securing arrangements, tarpaulins and closing arrangements for miscellaneous openings.
(b) Hatchways less than 3 m in length and breadth (requirements for larger hatchways are given in the relevant ship type Chapter, *see Pt 4 Ship Structures (Ship Types)*), cargo tank hatches, ventilators, air pipes, sounding pipes and discharges.

Hatch covers of other materials will be specially considered.

1.1.3 Hatch covers are to be fitted on holds intended for the carriage of perishable cargoes. Means are to be provided for making hatch covers weathertight by fitting tarpaulins or by sealing arrangements to the hatch cover and/or hatch coaming.

1.1.4 The requirements for scantlings and arrangements of the following types of hatch covers are defined in this Chapter:

(a) Self-supporting steel or aluminium, single plate hatch covers stiffened by webs, stiffeners or corrugations.
(b) Self-supporting steel or aluminium, double plate hatch covers having interior webs and stiffeners.
(c) Portable wood, steel or aluminium hatch covers used in conjunction with portable beams, fore and afters and crossbeams if necessary.
(d) Hatch covers on small openings to dry spaces.
(e) Hatch covers and coamings for cargo tanks and similar spaces.

1.1.5 The scantlings specified in the following Sections apply basically to uniformly loaded rectangular hatch covers, being simply supported and with stiffening members arranged primarily in one direction. When covers are stiffened otherwise or concentrated loads are applied, the scantlings are to be determined by direct calculations based on the permissible stresses and deflections given in *Table 11.2.2 Parameters for direct calculation* and are to be submitted for approval.

1.2 Symbols

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

h_{H} = hatch cover design head, *see Pt 3, Ch 3, 4 Design loading*

l_{o} = unsupported span of stiffening member, in metres

s = spacing of stiffeners, in metres

d_{w} = depth of stiffener, in mm

w = width of effective plating included in the section modulus, in metres

t = thickness of plating, in mm

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

I = moment of inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*.

■ *Section 2* Self-supporting steel hatch covers

2.1 Plating

2.1.1 The thickness of the plating of steel hatch covers is to be not less than required by *Table 11.2.1 Steel hatch cover scantlings*.

Table 11.2.1 Steel hatch cover scantlings

Item	Parameter	Requirements
Top plating for $h_{\text{H}} \le 0{,}75$ m	Thickness	The greater of: $t = 6s$ mm $t = 2$ mm, *see* Note
Top plating for $h_{\text{H}} > 0{,}75$ m	Thickness	The greater of: $t = 6{,}6s \sqrt[3]{h_{\text{H}}}$ mm $t = 2$ mm, *see* Note
Bottom plating for double plate covers	Thickness	The greater of: $t = 5s$ mm $t = 2$ mm, *see* Note

Webs and stiffeners	Section modulus Inertia Minimum thickness	$Z = 7{,}5 \times s \times h_{\text{H}} \times l_{\text{o}}^{2}$ cm^3 $I = 2{,}1 \times Z \times l_{\text{o}}$ cm^4 The greater of: $t = 0{,}018 d_{\text{w}}$ mm $t = 4$ mm
Effective plating to be included in the section modulus	Width	The lesser of: $w = 0{,}08t$ m $w = s$ m
The symbols are defined in *Pt 3, Ch 11, 1.2 Symbols 1.2.1*		
Note The top plating thickness may be reduced, when the plating is stiffened by swedges or equivalent, provided the maximum permissible stresses and deflections of *Table 11.2.2 Parameters for direct calculation* are not exceeded. Proposals are to be submitted for approval.		

Table 11.2.2 Parameters for direct calculation

Item	Bending stress in N/mm^2 (kgf/mm^2)	Shear stress in N/mm^2 (kgf/mm^2)	Deflection in metres
Steel covers	117,7 (12,0)	68,7 (7,0)	$0{,}004 l_{\text{o}}$
Aluminium covers	69,6 (7,1)	40,2 (4,1)	$0{,}004 l_{\text{o}}$

2.2 Webs and stiffeners

2.2.1 The scantlings of steel cover webs and stiffeners are to be not less than required by *Table 11.2.1 Steel hatch cover scantlings*.

■ *Section 3* Self-supporting aluminium hatch covers

3.1 General

3.1.1 This Section applies to hatch covers fabricated from aluminium alloys as defined in *Ch 8 Aluminium Alloys*of Lloyd's Register's (hereinafter referred to as 'LR') *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 When aluminium alloys other than those defined in *Ch 8 Aluminium Alloys* of LR's Rules for Materials are used, details of this composition and minimum mechanical properties of the material of the finished cover are to be submitted for approval. The approval will be based on the properties of the material, durability, etc.

3.2 Plating

3.2.1 The thickness of the plating of aluminium hatch covers is to be not less than required by *Table 11.3.1 Aluminium hatch cover scantlings*.

Table 11.3.1 Aluminium hatch cover scantlings

Item	Parameter	Requirements
Top plating for $h_H \leq 0,75$ m	Thickness	The greater of: $t = 8,4s$ mm $t = 2$ mm, *see* Note
Top plating for $h_H > 0,75$ m	Thickness	The greater of: $t = 9,25s$ $\sqrt[3]{h_H}$ mm $t = 2$ mm, *see* Note
Webs and stiffeners	Section modulus Inertia Minimum thickness	$Z = 12,75 \times b \times h_H \times l_o{}^2$ cm^3 $I = 3,7 \times Z \times l_o$ cm^4 The greater of: $t = 0,025d_w$ mm $t = 4$ mm
Effective plating to be included in the section modulus	Width	The lesser of: $w = 0,08t$ m $w = s$ m
The symbols are defined in *Pt 3, Ch 11, 1.2 Symbols 1.2.1*		
Note The top plating thickness may be reduced, when the plating is stiffened by swedges or equivalent, provided the maximum permissible stresses and deflections of *Table 11.2.2 Parameters for direct calculation* are not exceeded. Proposals are to be submitted for approval.		

3.3 Stiffeners

3.3.1 The scantlings of stiffeners and swedges of aluminium hatch covers are to comply with the requirements of *Table 11.3.1 Aluminium hatch cover scantlings*.

■ *Section 4*
Portable wood, steel or aluminium covers with portable beams

4.1 Wood, steel or aluminium covers

4.1.1 When wood covers are fitted, they are to have a finished thickness of not less than 25 mm, and are to be supported at their edges by beams spaced not more than 600 mm apart. The planks of the wood covers are to be connected at their underside by cross planks having the same thickness as the cover, a width of about 125 mm and spaced at a maximum distance of 1,5 m, *see Figure 11.4.2 Portable wood cover*.

4.1.2 The plating of steel covers is to comply with *Table 11.2.1 Steel hatch cover scantlings*, and the plating of aluminium covers is to comply with *Table 11.3.1 Aluminium hatch cover scantlings*.

4.1.3 The edges of the plating of steel or aluminium are to be adequately stiffened at their sides as necessary for the rigidity of the cover.

4.2 Portable beams, fore and afters and cross beams

4.2.1 Portable wood, steel or aluminium covers are to be supported by a system of beams and fore and afters with cross beams, where necessary, which are to have scantlings as required by *Table 11.4.1 Scantlings of supporting structure for hatch covers with portable beams*. For the layout of such arrangements, *see Figure 11.4.1 Hatch cover layout with portable beams*.

Table 11.4.1 Scantlings of supporting structure for hatch covers with portable beams

Item	Parameter	Requirements
Portable beams	Section modulus	$Z = 7{,}5 \times b_{\text{p}} \times h_{\text{H}} \times b^2$ cm^3 *see* Note
Fore and after	Section modulus	$Z = 8{,}5 \times b \times h_{\text{H}} \times l_{\text{a}}^2$ cm^3
Cross beam	Section modulus	$Z = 34 \times l_{\text{a}} \times h_{\text{H}} \times b$ cm^3
Additional fore and after (if fitted)	Section modulus	$Z = 4 \times b \times h_{\text{H}} \times l_{\text{a}}^2$ cm^3
Symbols		
Z and h_{H} as defined in *Pt 3, Ch 11, 1.2 Symbols 1.2.1* b_{p}, b and l_{a} = distances, in metres, as shown in *Figure 11.4.1 Hatch cover layout with portable beams*		
Note The section modulus of wood portable beams is to be fourteen times the section modulus of steel portable beams.		

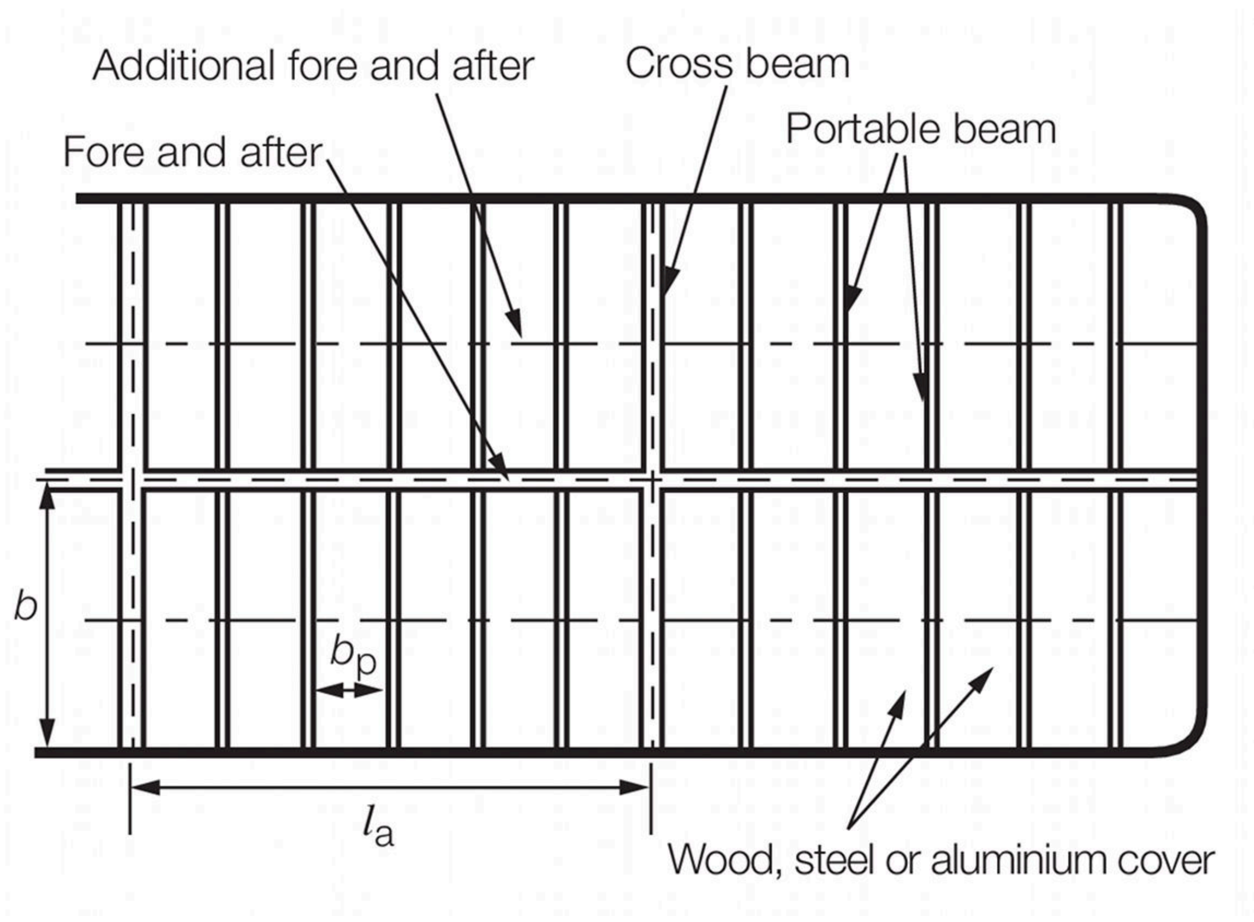


Figure 11.4.1 Hatch cover layout with portable beams

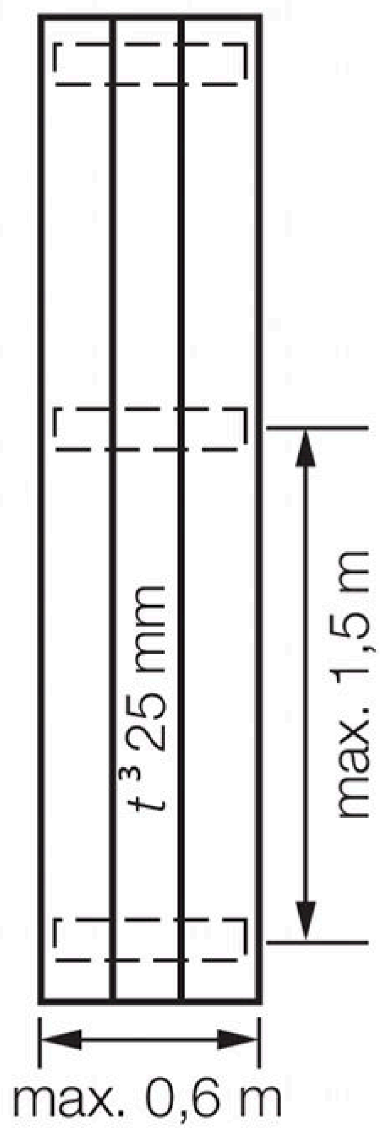


Figure 11.4.2 Portable wood cover

4.3 Quality of timber

4.3.1 The timber of covers and portable beams is to be of good quality and well preserved.

Section 5
Hatchways for cargo tanks

5.1 General

5.1.1 Hatchways for cargo tanks are to be made of steel. Their construction is to be such that no leakage of liquid or gas occurs. This is also applicable when the tank is subjected to internal pressure.

5.1.2 Hatch coamings on cargo tanks (may act as expansion trunk) are to be at least 500 mm in height. The thickness of the coaming is to be at least 6 mm.

5.1.3 The plating thickness and the stiffening of flat hatch covers are to comply with the requirements of *Table 11.5.1 Steel hatch covers for cargo tanks*.

Table 11.5.1 Steel hatch covers for cargo tanks

Item	Parameter	Requirements
Plating	Thickness	The greater of: $t = 9s + \sqrt{h_4}$ mm $t = 5$ mm
Stiffeners	Section modulus Inertia Minimum depth	$Z = 7{,}5 \times s \times l_e^{\ 2} \times h_4$ cm^3 $I = 2{,}1 \times Z \times l_e$ cm^4 $d_w = 50$ mm
Symbols		
t, *Z*, *I* and *s* are as defined in *Pt 3, Ch 11, 1.2 Symbols 1.2.1* h_4 = design pressure to be derived from the appropriate ship type Chapter, but to be taken not less than 1 m above the tank deck or 0,5 m above the top of the hatch cover whichever is the greater, in metres l_e = unsupported span of the stiffener, in metres, and is to be taken not less than 1 m		

5.1.4 Panel stiffeners are not normally required on hatch covers smaller than 500 x 500 mm, but efficient edge stiffening is to be fitted.

Section 6
Hatch cover securing arrangements and tarpaulins

6.1 Securing arrangements

6.1.1 Hatch covers are to be provided with securing arrangements to prevent undue movement of the covers, and to ensure suitable compression of the gasket if fitted. When toggles are fitted to ensure compression of the gasket, their number and spacing will be considered in relation to the rigidity of the hatch cover.

6.1.2 Toggles to cargo tank hatch covers are generally to be spaced not more than 450 mm apart, but the number and size are to be commensurate with the loads imposed upon them. When the cover is provided with suitable additional stiffening, the number of toggles may be reduced.

6.1.3 Hinges are not to be used for sealing arrangements unless they are adjustable in height.

6.1.4 On non-adjustable hinges the holes for the bolts are to be slotted in order to provide adequate vertical clearance in way to ensure equal packing pressure over the entire hatch by the toggles.

6.2 Tarpaulins

6.2.1 Where tarpaulins are fitted to make hatch covers weathertight, they are to be of ample strength and waterproof. Tarpaulins are to be secured by battens and wedges or equivalent arrangements.

■ *Section 7*
Small hatchways

7.1 General

7.1.1 This Section applies to small hatchways to dry spaces with a length and width less than 3 m.

7.1.2 If small hatchways are to be used as emergency exits they shall have a clear opening of not less than 0,36 m^2, and the smallest dimension shall be not less than 0,50 m.

7.2 Construction of coamings

7.2.1 The thickness of the hatch coaming is to be not less than the Rule thickness of the deck around the hatch. When the height of the coaming exceeds 300 mm the upper edge of the coaming is to be stiffened and the coaming may need to be supported by brackets or stays to the deck. Where the height of the coaming plate exceeds the spacing of the deck beams, the thickness of the coaming plate is to be increased or additionally stiffened.

7.3 Hatch covers

7.3.1 Hatch covers on hatches for access to dry spaces may be constructed of steel, aluminium or wood. The scantlings of these covers are to comply with the requirements of *Pt 3, Ch 11, 2 Self-supporting steel hatch covers*, *Pt 3, Ch 11, 3 Self-supporting aluminium hatch covers* or *Pt 3, Ch 11, 4 Portable wood, steel or aluminium covers with portable beams*, whichever is applicable. The edges of the covers are to be adequately stiffened.

7.3.2 Hatch covers are to be weathertight. The securing arrangements are to be adequate to ensure the weathertightness. Escape hatches are to be capable of being opened from either side.

■ *Section 8*
Miscellaneous openings

8.1 Companionways, doors and access openings on weather decks

8.1.1 Companionways on exposed decks are to be equivalent in strength and weathertightness to a deck-house in the same position. The height of the doorway sill above deck is to be not less than 100 mm, but at least 300 mm above the load waterline. When the companionway is leading to the engine room the height of the doorway sill above deck is to be not less than 400 mm.

8.1.2 For requirements for ships carrying dangerous liquids, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*.

8.2 Manholes

8.2.1 Manholes fitted in decks exposed to the weather are to be closed by strong watertight covers.

8.3 Windows, side scuttles and skylights

8.3.1 Windows and side scuttles fitted in the exposed sides of superstructures and deck-houses, or in the shell above the load waterline, are to have frames of a substantial construction, comparable with the surrounding structure. The glass thickness is to comply with the requirements of *Table 11.8.1 Glass thickness for windows and side scuttles*. Only non-opening windows or side scuttles are permitted in the shell, and the lower edge of the glass is to be at least 500 mm above the load waterline in any condition of list or trim. Windows or side scuttles in the shell are to be adequately protected against direct contact by efficient fenders or are to be recessed into the shell.

Table 11.8.1 Glass thickness for windows and side scuttles

Size of glass in mm	Thickness, in mm For windows and side scuttles in the following positions	
	Position A	Position B
300 x 425	6	6
355 x 500	6	6
400 x 560	6	6
450 x 630	6	6
500 x 710	8	6
560 x 800	8	6
900 x 630	10	6
1000 x 710	10	8
1100 x 800	12	8
Side scuttles	8	6

Note 1. Position A – The lower edge of the window is less than 2,5 m above the load waterline. Position B – The lower edge of the window is 2,5 m or more above the load waterline.

Note 2. The glass is to be toughened safety glass and the quality is to comply with ISO Standard 614 or equivalent standard.

8.3.2 Blinds and deadlights of steel or equivalent material need only be provided for windows or side scuttles in the shell and places where mechanical damage can occur. The number of blinds and deadlights to be provided is 20 per cent of the total number of openings but at least one cover for every size of opening.

8.3.3 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The scantlings of the coamings are to be as required by *Pt 3, Ch 11, 7 Small hatchways*. The construction of the glass in skylights is to be as for windows in the same position.

■ *Section 9*
Ventilators

9.1 General

9.1.1 The lower edge of ventilator openings on the open deck is to have a height of at least 500 mm above the load waterline, but not less than 100 mm above the deck, and are to be protected against ingress of water. When, due to service conditions, the height of the ventilator coaming is less than 500 mm above the load waterline, the hoods are to be provided with weathertight closing arrangements.

9.1.2 Special requirements for ventilation arrangements in certain types of ships are given in the relevant ship type Chapter in *Pt 4 Ship Structures (Ship Types)*.

9.2 Construction

9.2.1 The scantlings of exposed ventilator trunks and coamings are to be equivalent to scantlings of deck-houses in the same position. Ventilator trunks leading through cargo spaces or other areas where mechanical damage is likely to occur, are to be protected or additionally stiffened.

■ *Section 10* Air and sounding pipes

10.1 General

10.1.1 Air and sounding pipes are to comply with the requirements of *Pt 5, Ch 11, 10 Air and sounding pipes*. Name plates are to be affixed near their upper ends.

10.1.2 Striking plates of suitable thickness or their equivalent means, are to be fitted under all sounding pipes.

10.1.3 Air and sounding pipes leading through cargo containment areas or other spaces where mechanical damage is likely to occur, are to be well protected.

10.2 Height of air pipes

10.2.1 The height of air pipes from the upper surface of exposed decks to a point where water may have access below is normally to be not less than 300 mm, but the height above the load waterline in any loading condition is to be not less than 500 mm.

10.2.2 A lower height may be approved in cases where this is essential for the working of the ship, provided efficient means are fitted against ingress of water into the tank under all service conditions.

10.2.3 For air pipes on ships carrying dangerous goods, *see Pt 4, Ch 1 Dry Cargo Ships* and*Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk* respectively.

10.3 Closing appliances

10.3.1 Openings of air pipes of standard height as in *Pt 3, Ch 11, 10.2 Height of air pipes 10.2.1* are to be provided with spray tight arrangements, such as a bend in the upper part of the pipe or equivalent.

10.3.2 Sounding pipes are to be provided with permanently attached efficient means of closing to prevent the free entry of water.

10.3.3 Where the closing appliances on air pipes are not of an automatic type, provision is to be made for pressure/vacuum relieving.

10.3.4 The open ends of air pipes to fuel oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled and each opening is to be provided with a wire gauze diaphragm of incorrodible material.

■ *Section 11* Scuppers and sanitary discharges

11.1 General

11.1.1 All exposed decks and enclosed spaces are to be provided with efficient means of drainage.

11.1.2 Sanitary discharges may be led to suitable sanitary tanks or led overboard, provided the spaces to be drained are above the load waterline in any condition of list or trim.

11.1.3 Overboard discharges are to comply with the requirements of *Pt 5, Ch 11, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)* and *Pt 5, Ch 11, 3 Drainage of compartments, other than machinery spaces*.

11.1.4 Scuppers and discharges should not normally pass through fuel oil tanks. Where unavoidable, the arrangements are to be submitted for approval.

11.2 Scantlings

11.2.1 Scuppers and discharge pipes which pass through the shell below the load waterline are to have a thickness, t, not less than $t = 0{,}042\delta_p + 6{,}5$ mm,

where

δ_p is the internal diameter of the pipe in mm, but need not exceed 12,5 mm.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ships covered by *Pt 4 Ship Structures (Ship Types)*, and requirements are given for rudders, fixed and steering nozzles, steering gears, bow and stern thrust unit structure, and anchoring and mooring equipment.

1.1.2 The requirements of this Chapter are based on the assumption of heavy traffic on relatively narrow waterways through densely populated areas. When ships are intended to be used on waterways with service conditions different from this, they will receive special consideration.

1.1.3 Attention is also drawn to additional requirements of National or International Authorities, e.g. 'Inspection Regulations' of the C.C.N.R. with respect to steering capabilities and requirements for anchoring and mooring equipment.

1.2 Navigation in ice

1.2.1 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in *Pt 3, Ch 9, 3 Strengthening for navigation in ice*. The requirements for rudders and sternframes are also applicable to nozzles.

■ *Section 2* Rudders

2.1 General

2.1.1 Requirements are given in this Section for double and single plate rudders and also for certain types of higher efficiency rudders.

2.1.2 The scantlings of flanking rudders (rudders fitted forward of the propeller to improve steering when navigating astern) are to be in accordance with the requirements for rudders fitted abaft the propeller. However, the scantlings are to be not less than required for an astern speed equal to the normal service speed ahead. This type of rudder is to be provided with stops at a maximum angle of helm of 45°.

2.1.3 The scantlings of a bow rudder are to be in accordance with the requirements for rudders out of the propeller slip stream applying the maximum speed, ahead or astern, at which the rudder will be used or half the service speed, whichever is the greater. Efficient arrangements are to be provided for locking the rudder in the centreline position when not in use, *see Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.4*.

2.1.4 Rudder systems of special design will be considered on the basis of these Rules and full details on the loadings of these rudders are to be given; model tests may be required to support the calculations.

2.1.5 Rudders are to be efficiently supported in the ship's structure by means of suitable carriers in the steering gear flat, or in the solepiece gudgeons. Where the weight of the rudder is supported by carrier bearings the structure in way is to be adequately strengthened and the deck plating increased in thickness.

2.1.6 Rudder stocks are to be enclosed by watertight trunks or tubes which are to be fitted with an efficient watertight gland or other approved type of seal when the top of the trunks (steering gear flat) is less than 300 mm above the deepest waterline in any trimmed condition.

2.1.7 Arrangements to prevent the rudders from lifting are to be fitted. Their strength and that of the supporting structure is to be such that damage to the steering gear in case of touching bottom is prevented, *see Pt 5, Ch 15, 2.1 General 2.1.2.(b)*.

2.2 Rudder stock and bearings

2.2.1 The scantlings of the rudder stock are to be not less than required by *Table 12.2.1 Rudder stock diameter*.

Table 12.2.1 Rudder stock diameter

Item	Requirement
(1) Basic stock diameter, δ_S, at and below lowest bearing for mild steel	$\delta_s = 52,4K_R \sqrt[3]{f(v+5,6)^2 \times \sqrt{A_R{}^2 x_p{}^2 + N^2}}$ mm
(2) Stock diameter, δ_{SO}, corrected for higher tensile steel	$\delta_{SO} = \delta_S \sqrt[3]{k_O}$
(3) Diameter in way of tiller, δ_{SU}	δ_{su} = δ_{SO} in (1) with $N = 0$ For spade rudders: $\delta_{SU} \geq 0,7\delta_S$
Symbols	
f = coefficient dependent on type of rudder profile and rudder angle, *see Table 12.2.5 Rudder coefficient f* K_o = material factor For $\sigma_o > 235$ (24) = $(235/\sigma_o)^{0,75}$ $(24/\sigma_o)^{0,75}$ For $\sigma_o \leq 235$ (24) = $(235/\sigma_o)$ $(24/\sigma_o)$ k_R = rudder coefficient, *see Table 12.2.2 Rudder coefficient kR* x_P = horizontal distance, in metres, *see Table 12.2.3 Position of centre of pressure* A_R = rudder area, in m^2 N = coefficient dependent on rudder support arrangement, *see Table 12.2.4 Pintle arrangement coefficient, N see Fig. 12.2.1* V = maximum service speed with the ship in the loaded condition, in km/h P_L = lateral force on rudder acting at centre of pressure blade = $117,5K_R f(V + 5.6)^2 A^R$	
NOTE Where the astern speed is expected to be more than 0,5 × the speed ahead, δ_S will be specially considered. σ_o is to be taken not greater than 70 per cent of the ultimate tensile strength or 450 N/mm^2 (45,9 kgf/mm^2), whichever is the lesser, so is not to be less than 200 N/mm^2, *see Ch 5, 2.4 Mechanical tests 2.4.6* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* .	

Table 12.2.2 Rudder coefficient k_R

Design criteria	k_R
Rudder in propeller slipstream	0,248
Rudder out of propeller slipstream	0,235
Barge – non-self-propelled	0,226
Symbols	
k_R = rudder coefficient for use in *Table 12.2.1 Rudder stock diameter* and *Table 12.2.9 Rudder couplings to stock*	

Table 12.2.3 Position of centre of pressure

Design criteria	Value of x_P to be used in *Table 12.2.1 Rudder stock diameter*
Rectangular rudders	$x_P = (0{,}33x_B - x_L)$ but not less than $0{,}12x_B$
Non-rectangular rudders	x_P as calculated from geometric form (*see* Note) but not less than $\dfrac{0,12A_R}{y_R}$
Symbols	
x_B = breadth of rudder, in metres x_L = horizontal distance from leading edge of the rudder, to the pintles, or axle, in metres x_P = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure, in metres x_S = horizontal length of any rectangular strip of rudder geometric form, in metres y_R = depth of rudder on centreline of stock, in metres A_R = rudder area, in m^2	
NOTE For rectangular strips the centre of pressure should be assumed to be located $0{,}33x_S$ abaft leading edge of strip.	

Table 12.2.4 Pintle arrangement coefficient, *N see* Fig. 12.2.1

Support arrangement	Value of N
Two or more pintles, *see Figure 12.2.1 Pintle arrangements*	$N = 0$
One pintle	$N = A_1(0{,}67y_1 + 0{,}17y_2)$
No pintle	$N = A_2(y_1 + 0{,}5y_3)$

Symbols	
y_1, y_2, y_3 =	vertical dimensions, in metres, *see Figure 12.2.1 Pintle arrangements*
A_1, A_2 =	rudder areas, in m^2, *see Figure 12.2.1 Pintle arrangements*
N =	coefficient for use in *Table 12.2.1 Rudder stock diameter*

Table 12.2.5 Rudder coefficient *f*

Rudder angle	2 × 35°	2 × 45°	2 × 55°
Rudder profile Type 1	1,0	1,23	1,43
Rudder profile Type 2	1,60	1,97	-
Rudder profile Type 3	1,15	1,42	1,64
Symbols			
Rudder profile Types 1, 2, and 3, *see Figure 12.2.3 Rudder profile types*			
f = rudder coefficient for use in *Table 12.2.1 Rudder stock diameter* and *Table 12.2.9 Rudder couplings to stock*. Intermediate values may be obtained by interpolation			

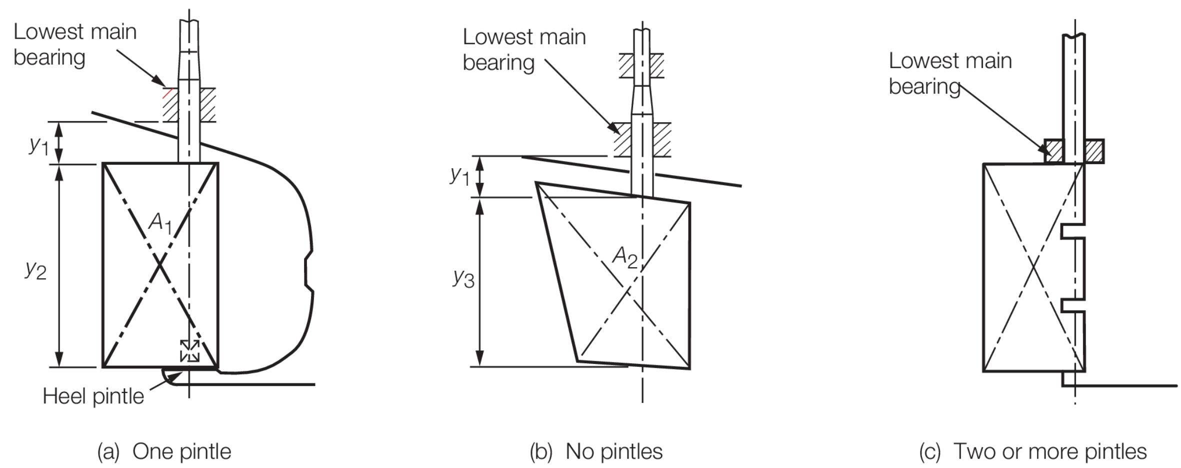


Figure 12.2.1 Pintle arrangements

2.2.2 For rudders having an increased diameter of the rudder stock in way of the rudder, *see Figure 12.2.2 Taper of rudder stock*, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the upper bearing and further to the diameter at tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper. The design of the upper part of the rudder stock and of the upper rudder stock bearing is to take account of any forces which may be imposed by the steering engine, especially in the case where two or more rudders are activated by one steering engine.

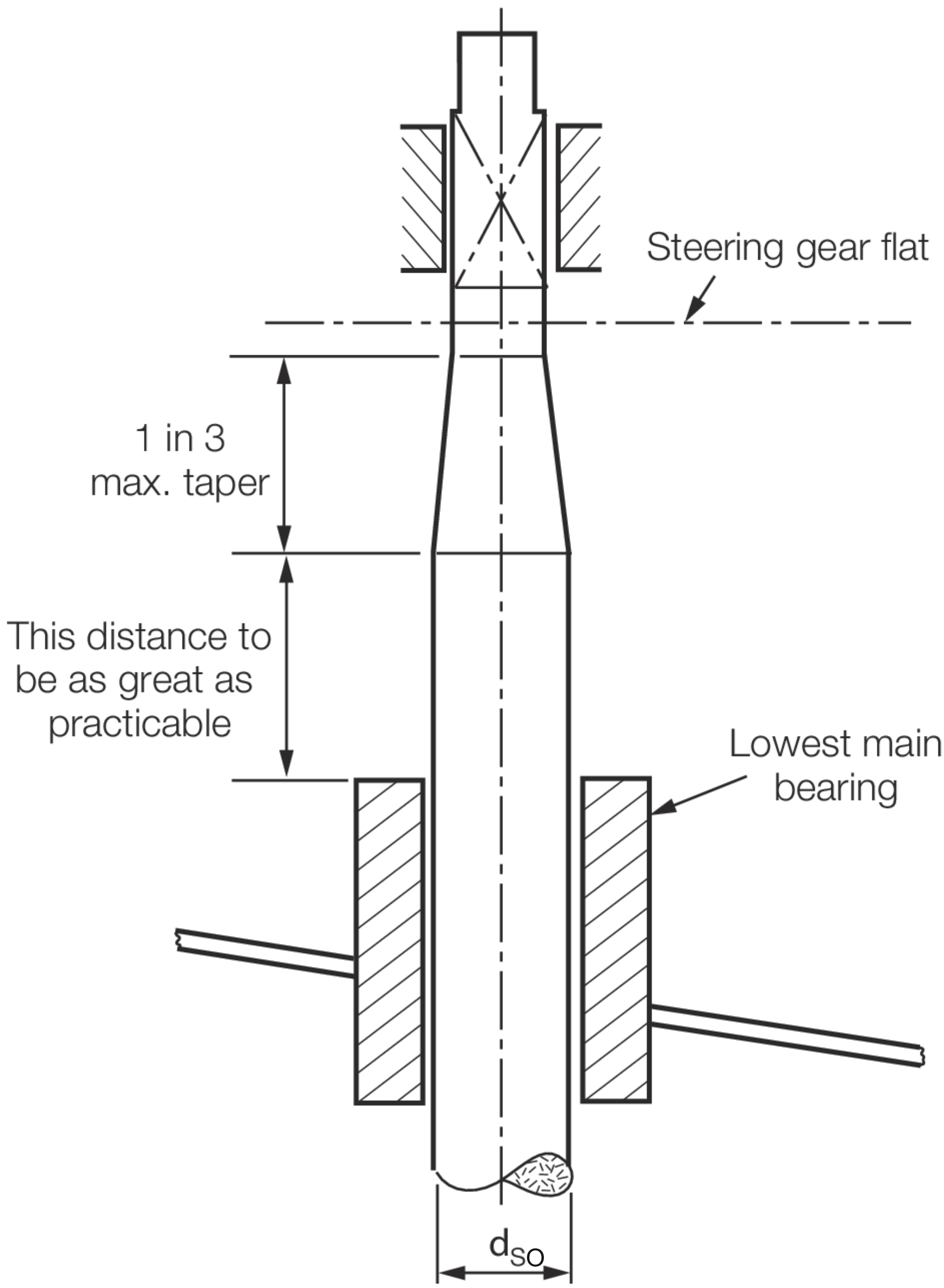


Figure 12.2.2 Taper of rudder stock

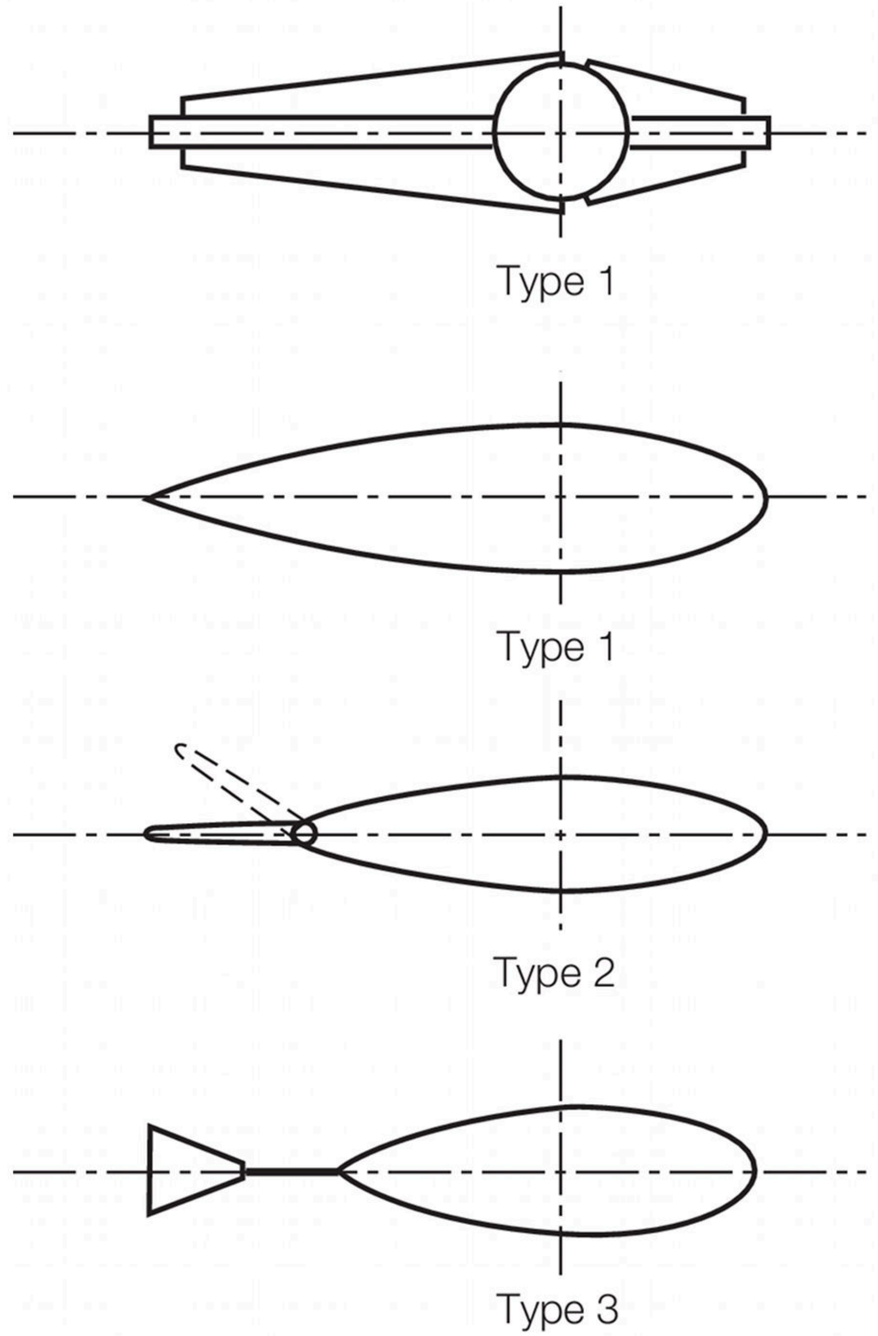


Figure 12.2.3 Rudder profile types

2.2.3 Sudden changes of section or sharp corners in way of the rudder coupling, and shoulders for rudder carriers are to be avoided. Jumping collars are not to be welded to the rudder stock. Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.2.4 The design of the lowest bearing is to comply with the requirements of *Table 12.2.6 Lowest main bearing requirements*.

Table 12.2.6 Lowest main bearing requirements

Item	Requirements	
Lowest main bearing	Depth z_B, in mm	
	$1{,}5\delta_{SO} \geq z_B \geq 1{,}0\delta_{SO}$ For spade rudders: $1{,}5\delta_{SO} \geq z_B \geq 1{,}3\delta_{SO}$	
Bearing pressure (on the projected area of the lowest main bearing), where the area is to be taken as the projected length × diameter	Bearing material	Maximum pressure, in N/mm^2 (kgf/cm^2)
	Metal Synthetic Lignum Vitae	6,87 (70,0) 4,41 (45,0) 2,45 (25,0)
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Clearance, in mm
	Metal (*see* note)	$0{,}001\delta_{SO} + 1{,}0$
	Synthetic	$0{,}002\delta_{SO} + 1{,}0$ but not less than 1,5
Symbols		
z_B = depth of lowest bearing, in mm δ_{SO} = basic stock diameter, given by *Table 12.2.1 Rudder stock diameter*, in mm		
NOTE For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained.		

2.2.5 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the stocks and pintles are to be of weldable quality steel, and details of the procedure are to be submitted, *see also Pt 3, Ch 12, 2.2 Rudder stock and bearings 2.2.6*.

2.2.6 Where it is proposed to use stainless steel liners and bushes for rudder stock and/or pintle bearings, the chemical composition and mechanical properties are to be submitted for approval. Materials for bushes and liners are to have a suitable difference in hardness. Synthetic rudder bearing materials are to be of a type approved by Lloyd's Register (hereinafter referred to as LR).

2.3 Rudder construction – Doubled plated

2.3.1 The scantlings of a double plated rudder are to comply with *Table 12.2.7 Double plated rudder construction*, but the thickness of the rudder plating may require to be increased in way of the rudder coupling and the heel pintle.

Table 12.2.7 Double plated rudder construction

Item	Requirements
(1) Side plating	$t = 3y_W (1{,}45 + 0{,}1\sqrt{\delta_{SO}}) + 2$ mm
(2) Webs - vertical and horizontal	As (1) above

(3) Top and bottom plates	As (1) above using y_W = maximum rudder width, in metres, at top or bottom, but not less than 0,9 m
(4) Nose plates	$t_N \geq 1{,}25t$ from (1)
(5) Mainpiece - fabricated rectangular, *see* Note	Breadth and width $\geq \delta_{SO}$ $t_M = 5 + 0{,}56\sqrt{\delta_{SO}}$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending $\leq 5{,}0$ kgf/mm$_2$
(6) Mainpiece - tubular, *see* Note	Inside diameter $\geq \delta_{SO}$ t_M as for (5) Side plating as for (1) Bending stress as for (5)
Symbols	
t = thickness, in mm t_M = thickness of side plating and vertical webs forming mainpiece or of tube, in mm t_N = thickness of nose plate, in mm y_W = vertical spacing, in metres, of the horizontal webs, but is not to exceed 0,9 m x_B = breadth of rudder on centreline of stock, in metres δ_{SO} = basic stock diameter, given by *Table 12.2.1 Rudder stock diameter*, in mm	
Note The section modulus of the lower third of the mainpiece may be gradually reduced to two-thirds the section modulus required by this Table. For spade rudders, *see Pt 3, Ch 12, 2.3 Rudder construction – Doubled plated 2.3.3*.	

2.3.2 Adequate hand or access holes are to be arranged in the rudder plating in way of the pintles as required and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

2.3.3 In order to minimize the risk of damage to the steering gear, *see Pt 5, Ch 15, 2.1 General 2.1.2.(b)*, it is recommended that the lower third part of spade type rudders, *see Figure 12.2.1 Pintle arrangements*, be constructed without mainpiece or vertical webs. The section modulus of the mainpiece may be gradually tapered down to 50 per cent of the value required by *Table 12.2.7 Double plated rudder construction*.

2.3.4 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness or 20 mm whichever is the greater. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm. Alternatively the side plating may be fitted in panels, fillet welded all round either directly on to webs of increased thickness or on to flat bars on the webs.

2.3.5 Double plate rudders are to be efficiently coated internally and means for draining the rudder are to be provided in way of the lowest part of the rudder when the rudder is mounted in its normal position.

2.3.6 For the testing of rudders, *see Table 1.7.2 Testing requirements* in Chapter 1.

2.3.7 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.4 Rudder construction – Single plated

2.4.1 The scantlings of a single plated rudder are to be not less than required by *Table 12.2.8 Single plate rudder construction*.

Table 12.2.8 Single plate rudder construction

Item and parameter	Requirements
Blade thickness	The greater of: $t = 5 + 0{,}02\delta_{SO} + 10y_W$ mm $t = 10$ mm
Section modulus of arms	$Z = 0{,}25 \times y_W^{\ 2} \times x_W(V + 5{,}6)^2$ cm^3
Diameter of mainpiece	Diameter = δ_{SO} mm, *see* Note to *Table 12.2.7 Double plated rudder construction*
Symbols	
t = thickness, in mm x_W = breadth of rudder blade aft of stock, in metres y_W = vertical spacing, in metres, of the arms, but is not to exceed 0,9 m V = ship's speed, in km/h Z = section modulus, in cm^3 δ_{SO} = basic stock diameter, given by *Table 12.2.1 Rudder stock diameter*, in mm.	

2.4.2 For spade type rudders, *see Pt 3, Ch 12, 2.3 Rudder construction – Doubled plated 2.3.3*.

2.4.3 Rudder arms are to be efficiently attached to the mainpiece.

2.5 Rudder couplings

2.5.1 Rudder coupling design is to be in accordance with *Table 12.2.9 Rudder couplings to stock*. Conical couplings will be specially considered.

Table 12.2.9 Rudder couplings to stock

Arrangement	Parameter	Requirements	
		Horizontal coupling	Vertical coupling

Bolted couplings	n	≥ 6	≥ 8
	δ_b	$\dfrac{0,65\ \delta_S \sqrt{k_O}}{\sqrt{n}}$	$\dfrac{0,81\ \delta_S \sqrt{k_O}}{\sqrt{n}}$
	m	$0{,}00071 n \delta_S \sqrt{k_O} \delta_b{}^2$	$0{,}00043 \sqrt{k_O} \delta_S{}^3$
	t_f	$\geq \delta_b$ (*see* Note 1)	δ_b
	α_{max} (*see* Note 2)	$\left(53,82 - 35,29 k_1\right)\dfrac{\delta_S{}^3}{P_L h 10^3} - \left(1,8 - 6,3 \dfrac{R}{\delta_{sO}}\right)\dfrac{t_f - t_{fa}}{t_{fa}}$	-
	$\alpha_{as\ built}$ (*see* Note 2)	$\leq \alpha_{max}$	-
	w_f	$0{,}67\delta_b$	$0{,}67\delta_b$
Symbols			

h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see Pt 3, Ch 12, 2.5 Rudder couplings 2.5.1*

k_1 = the greater of k_s and k_f

k_f = upper coupling flange material factor

k_s = rudder stock material factor

m = first moment of area of bolts about centre of coupling, in cm^3

n = number of bolts in coupling

t_f = minimum thickness of coupling flange, in mm

t_{fa} = as built flange thickness, in mm

w_f = width of flange material outside the bolt holes, in mm

R = palm radius between rudder stock and connected flange, not smaller than $\frac{\delta_{SO}}{10}$, in mm

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

$= \frac{0,73}{\sqrt{\frac{R}{\delta_{SO}}}}$

α_{max} = maximum allowable stress concentration factor

δ_b = diameter of coupling bolts, in mm

δ_{SO}, δ_{SU} = rudder stock diameters as defined in *Table 12.2.1 Rudder stock diameter*

P_L = lateral force acting on the rudder, in N, is to be calculated for both ahead and astern conditions. The greater of the two values is to be used

P_L = lateral force on rudder acting at centre of pressure blade, *see Table 12.2.2 Rudder coefficient kR*

k_R = rudder coefficient,*see Table 12.2.2 Rudder coefficient kR*

k_o = material factor as defined in *Table 12.2.2 Rudder coefficient kR*, for the appropriate item

M_T = maximum turning moment applied to stock, and is take to be as the greates of:

(a) $\frac{11,1\delta_{SU}^3}{k_O}$ N mm

(b) The torque generated by the steering gear att he maximum working pressure (*see Pt 5, Ch 15, 1.2 Definitions 1.2.8*)

f = rudder coefficient, *see Table 12.2.5 Rudder coefficient f*

V = maximum service speed with the ship in the loaded condition, in km/h

A_R = rudder area, in m^2

Note 1. For spade rudders with horizontal coupling, t_f is not to be less than 0,25δ_{SO}.

Note 2. This requirement is applicable only for spade rudders with horizontal couplings, *see Pt 3, Ch 12, 2.5 Rudder couplings 2.5.1*.

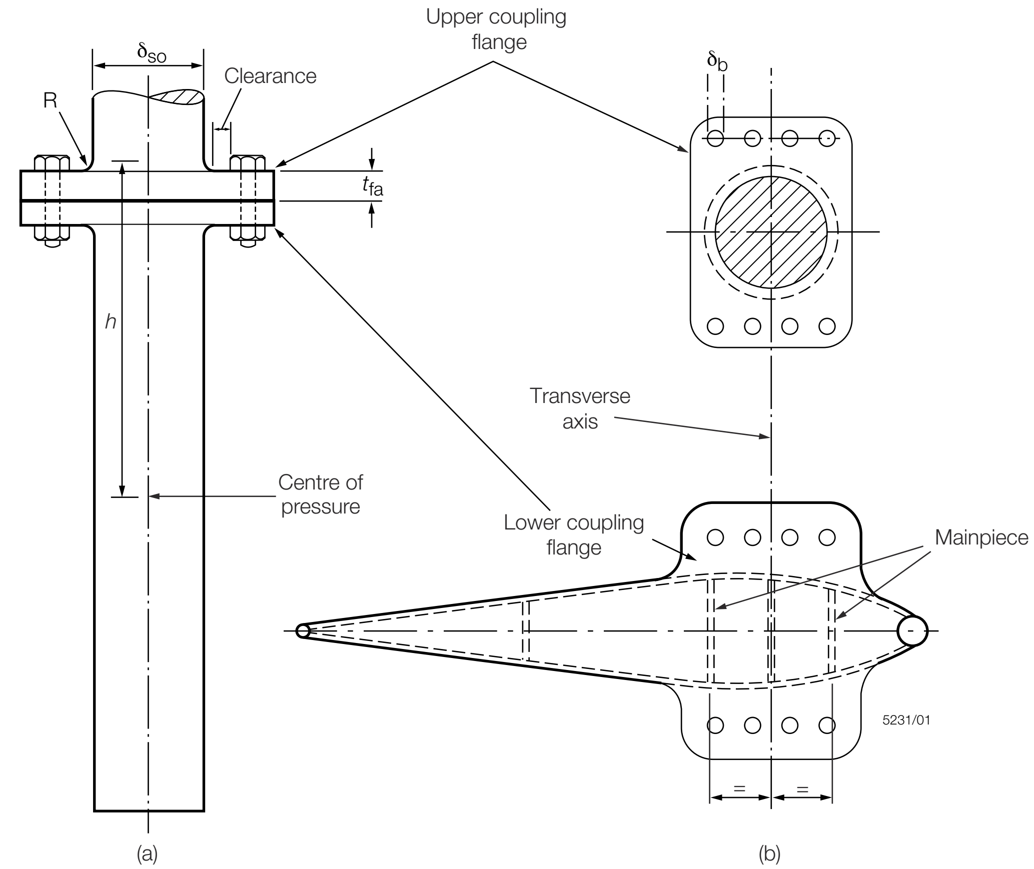


Figure 12.2.4 Rudder stock connection

2.5.2 For rudders with horizontal coupling arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is to be not less than 600°C.

2.5.3 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, *R*, *see Pt 3, Ch 12, 2.5 Rudder couplings 2.5.1*. The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth and to the Surveyor's satisfaction.

2.5.4 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see Pt 3, Ch 12, 2.5 Rudder couplings 2.5.1*.

2.6 Pintles

2.6.1 Rudder pintles and their bearings are to comply with the requirements of *Table 12.2.10 Pintle requirements*.

2.6.2 When coned pintles are fitted special attention is to be paid to the fit of the pintle taper into its housing. The pintle taper is not to exceed one in six on the diameter, but to facilitate removal of the pintles it is recommended that the taper be not less than 1 in 12 on the diameter.

Table 12.2.10 Pintle requirements

<table>
<tr><th>Item</th><th colspan="2">Requirements</th></tr>
<tr><td>(1) Pintle diameter (measured outside liner if fitted)</td><td colspan="2">$$\delta_{PL} = 31 + 2,25V\sqrt{A_{PL}} \text{ mm}$$ where for single pintle rudders: $$A_{PL} = \frac{A_R C_{CP}}{C_{PL}} \text{ m}^2$$ and for rudders with two or more pintles: $$A_{PL} = \frac{A_R}{N_{PL}} \text{ m}^2$$</td></tr>
<tr><td>(2) Bearing length</td><td colspan="2">$z_{PB} \geq 1,2\delta_{PL}$</td></tr>
<tr><td>(3) Gudgeon thickness in way of pintle (measured outside bush if fitted)</td><td colspan="2">$b_G \geq 0,5\delta_{PL}$</td></tr>
<tr><td rowspan="3">(4) Recommended pintle clearance (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)</td><td>Bearing material</td><td>Clearance, in mm (on diameter)</td></tr>
<tr><td>Metal</td><td>$0,001\delta_{PL} + 1,0$</td></tr>
<tr><td>Synthetic</td><td>$0,002\delta_{PL} + 1,0$
but not less than 1,5</td></tr>
<tr><td colspan="3">Symbols</td></tr>
<tr><td colspan="3">b_G = thickness of gudgeon material in way of pintle, in mm
z_{PB} = pintle bearing length, in mm
A_{PL} = rudder area supported by the pintle, in m^2
C_{CP}, C_{PL} = dimensions, in metres, as indicated in Figure 12.2.5 Dimensions for pintle requirements
N_{PL} = number of pintles on the rudder
V = ship speed, in km/h, but not less than 12 km/h
δ_{PL} = pintle diameter, in mm</td></tr>
<tr><td colspan="3">Note Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.</td></tr>
</table>

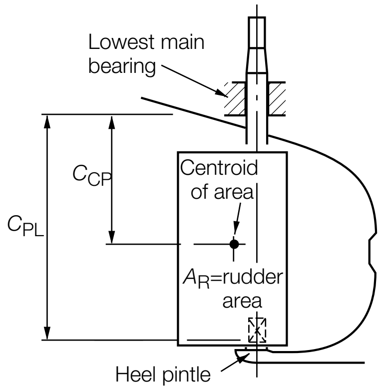


Figure 12.2.5 Dimensions for pintle requirements

Section 3
Fixed and steering nozzles

3.1 General

3.1.1 Fixed and steering nozzles are, in general, to be in accordance with *Pt 3, Ch 13, 3 Fixed and steering nozzles* of the *Rules and Regulations for the Classification of Ships, July 2022*.

Section 4
Bow and stern thrust unit structure

4.1 Unit wall thickness

4.1.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than either the thickness of the surrounding shell plating plus 10 per cent or 9 mm, whichever is greater.

4.2 Framing

4.2.1 The unit is to be framed to the same standard as the surrounding shell plating.

4.2.2 The unit is to be adequately supported and stiffened.

Section 5
Equipment

5.1 Scope

5.1.1 The requirements for anchoring equipment for the various ship types provided by this Section are for service in **Zone 1**, **Zone 2** and **Zone 3**, *see Pt 1, Ch 2, 2 Character of classification and class notations*.

5.1.2 The anchors, cables, towlines and mooring wires required by this Section are based on the following conditions:

(a) Current of river, maximum 8 km/h;

(b) Anchoring grounds being such that an approved standard type anchor has a holding power in the particular soil not less than six times its weight.

5.1.3 When ships are intended to operate under environmental conditions differing from those detailed in *Pt 3, Ch 12, 5.1 Scope 5.1.2*, the anchoring and mooring equipment will be specially considered and may be modified to suit the actual conditions. A possible reduction in the requirements as in *Pt 3, Ch 12, 5.10 Correction of required minimum mass 5.10.2* is, however, not permitted when the ship has to comply with the regulations stipulated in *Pt 3, Ch 12, 5.1 Scope 5.1.4*.

5.1.4 The equipment of Inland Waterway vessels intended to navigate on the river Rhine and other European waterways must also comply with the, European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN) as applicable.

5.2 General

5.2.1 To entitle a ship to the figure **1** in its character of classification, the equipment is to be provided in accordance with this Section or in accordance with established National or International Regulations as agreed by the Committee, e.g. the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN).

5.2.2 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned. *See also Pt 1, Ch 2, 2.2 Character symbols 2.2.2*.

5.2.3 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned. *See also Pt 1, Ch 2, 2.2 Character symbols 2.2.2*.

5.2.4 For classification purposes, the character figure **1**, or either of the character letters **N** or **T**, is to be assigned.

5.3 Symbols and definitions

5.3.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

T as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

L_{oa} is the overall length of the hull, in metres

B_e = the maximum breadth of the hull, in metres, measured to the outer edge of the shell plating at draught T

T_e = the maximum draught measured to the lowest outer part of the keel plate.

5.4 Bow anchors

5.4.1 For ships carrying cargoes, the total mass P of the bow anchors is to be calculated in accordance with the following formula:

$$P = k B_e T_e \text{ [kg]}$$

where

$$k = c\sqrt{\frac{L_{oa}}{8B_e}}$$

c = Coefficient as per *Table 12.5.1 Values of coefficient c* .

For pushbarges $k = c$

Table 12.5.1 Values of coefficient *c*

Deadweight, in metric tonnes	Coefficient c
< 400	45
> 400 ≤ 650	55

> 650 ≤1000	65
> 1000	70

5.4.2 For passenger ships and ships not intended for the carriage of goods, such as tugs and launches, the total mass *P* of the bow anchors is to be calculated in accordance with the following formula, *see also Pt 3, Ch 12, 5.4 Bow anchors 5.4.4*:

$$P = k B_e T_e \text{ [kg]}$$

where

$$k = c\sqrt{\frac{L_{oa}}{8B_e}}$$

c = Coefficient as per *Table 12.5.1 Values of coefficient c* , except that, for obtaining this empirical coefficient, the maximum displacement in m^3 instead of the deadweight in metric tonnes shall be used.

5.4.3 The number of anchors is to be in accordance with *Pt 3, Ch 12, 5.8 Number of anchors*.

5.4.4 For passenger ships intended to navigate on the Rhine downstream of 855 km (Emmerich) for which a certificate needs to be issued in accordance with the Rhine Inspection Regulations, attention is drawn to the increased anchor mass requirements as per Chapter 10 of the Rhine Inspection Regulations.

5.5 Stern anchors

5.5.1 Stern anchors are not required for:

(a) Vessels for which the calculated stern anchor mass is less than 150 kg;
(b) Barges being pushed.

5.5.2 Vessels referred to in *Pt 3, Ch 12, 5.4 Bow anchors 5.4.1* with an overall length not exceeding 86 m shall be equipped with a stern anchor having a total mass of at least 25 per cent of mass *P* calculated in accordance with *Pt 3, Ch 12, 5.4 Bow anchors 5.4.1*.

5.5.3 Vessels with an overall length exceeding 86 m shall be equipped with one or two stern anchors with a total mass of at least 50 per cent of mass *P* calculated in accordance with *Pt 3, Ch 12, 5.4 Bow anchors 5.4.1*.

5.5.4 Vessels intended to propel rigid convoys not exceeding 86 m in length shall be equipped with stern anchors of a total mass at least equal to 25 per cent of the mass *P* calculated in accordance with *Pt 3, Ch 12, 5.4 Bow anchors 5.4.1* using the maximum main dimensions of the formation. The composition and maximum dimensions of the formation to be pushed will be entered in the class certificate.

5.5.5 Vessels intended to propel rigid convoys exceeding 86 m in length shall be equipped with stern anchors of a total mass at least equal to 50 per cent of the mass *P* calculated in accordance with *Pt 3, Ch 12, 5.4 Bow anchors 5.4.1* using the maximum main dimensions of the formation. The composition and maximum dimensions of the formation to be pushed will be entered in the class certificate.

5.5.6 The required mass calculated in accordance with *Pt 3, Ch 12, 5.5 Stern anchors 5.5.2* applies to ordinary stockless stern anchors. When anchors of a design approved for the designation 'High Holding Power' (HHP) are used, the mass of each such anchor may be reduced by the percentages given in ESI-II-9 Section 1 of *European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN)* subject to agreement with the competent authority.

5.6 High holding power anchors

5.6.1 When high holding power anchors are used as bower anchors, the mass of each such anchor may be 75 per cent of the mass calculated for ordinary stockless bower anchors.

5.6.2 Anchor designs for which approval is sought as high holding power anchors are to be tested to show that they have holding powers of at least twice those of approved standard stockless anchors of the same mass. For holding power test requirements relating to high holding power anchors, *see Ch 10, 1.3 Anchor holding power tests for HHP and SHHP anchors* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

5.6.3 The anchor is to be suitable for the ship's use and is not to require prior adjustment or special placement on the riverbed.

5.6.4 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the riverbed without undue delay and will remain stable, for holding forces up to those required by *Pt 3, Ch 12, 5.6 High holding power anchors 5.6.2*, irrespective of the angle or position at which they first settle on the river bed when dropped from a normal type of hawse pipe. In case of doubt, a demonstration of these abilities may be required.

5.7 Special anchors

5.7.1 For ships operating in European inland waterways, the required mass calculated in accordance with *Pt 3, Ch 12, 5.4 Bow anchors*, *Pt 3, Ch 12, 5.5 Stern anchors* or *Pt 3, Ch 12, 5.6 High holding power anchors*, as applicable, can be reduced by the percentages given in ESI-II-9 Section 1 of *European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN)* subject to agreement with the competent authority.

5.7.2 Special anchors are to be of an approved design and, in addition to the testing requirements given in *Ch 10 Equipment for Mooring and Anchoring* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*, are to be tested in accordance with the requirements of Article 13 of the *European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN)*.

5.8 Number of anchors

5.8.1 The total mass *P* as required for bow anchors may be distributed between one or two anchors.

5.8.2 Where a vessel is equipped with only a single bow anchor and the hawse pipe is located on the centreline, the mass *P* may be reduced by 15 per cent.

5.8.3 The total mass required for stern anchors for pushers and vessels whose maximum length exceeds 86 m may be distributed between one or two anchors.

5.8.4 The mass of the lightest anchor shall not be less than 45 per cent of the required total mass for the anchors.

5.9 Chain cables

5.9.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged.

5.9.2 The minimum breaking load of chain cables shall be determined in accordance with *Table 12.5.2 Minimum breaking load R of chain cable* .

Table 12.5.2 Minimum breaking load *R* of chain cable

Anchor mass [kg]	*R*[kN]
≤ 500	0,35*P*
> 500 and ≤ 2000	$\left(0,35 - \frac{P' - 500}{15\,000}\right)P'$
> 2000	0,25*P*’
Symbols	
P’ = The theoretical mass of the anchor as determined in accordance with *Pt 3, Ch 12, 5.4 Bow anchors*	
Where the actual anchor mass is greater than required, P ’ is to be taken as the actual anchor mass	
Where the actual anchor is an anchor of the High Holding Power type, the equivalent mass of a normal anchor is to be used for *P*’	

5.9.3 The minimum length of each chain cable shall be determined in accordance with *Table 12.5.3 Minimum length of chain cable*.

Table 12.5.3 Minimum length of chain cable

Overal length of vessel, L_{oa} in m	Minimum length of chain cable, in metres	
	Zones 2 and 3	Zone 1
< 30	40	L_{oa} + 10 with a minimum of 40 m and need not be greater than 100 m
≥ 30 and ≤ 50	L_{oa} + 10	
> 50	60	

5.9.4 Chain cables may be either short link or stud link and of mild steel or special quality steel, in accordance with the requirements of *Ch 10 Equipment for Mooring and Anchoring* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* and are to be graded in accordance with *Table 12.5.4 Chain cable steel grades*.

Table 12.5.4 Chain cable steel grades

Grade	Material	Tensile strength	
		N/mm^2	(kgf/mm^2)
U1	Mild steel	300–490	(31–50)
U2(a)	Special quality steel (wrought)	490–690	(50–70)
U2(b)	Special quality steel (cast)	490–690	(50–70)

5.9.5 The use of steel wires instead of anchor chains is permitted. Steel wires are to have a breaking strength not less than that required for chain cables and their length is to be 20 per cent greater than the required length of the chain cable.

5.9.6 Where wire rope is used in lieu of chain cable for anchoring, galvanised wire rope with an independent wire core in accordance with *Ch 10, 6 Steel wire ropes* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* is to be used. Wire rope terminal fittings are to comply with an acceptable Code or standard. The strength of terminations, connecting fittings, shackles or links is not to be less than that of the anchor line.

5.9.7 In conjunction with HHP anchors, only Grade U2 or ISO Grade 40 chain cable is to be used, except that, when desired by Owners, for HHP anchors having a mass of 300 kg or less, Grade U1 chain cable may be used, provided the required breaking strength of the chain cable as per *Pt 3, Ch 12, 5.9 Chain cables 5.9.2* is increased by 10 per cent.

5.9.8 The form and proportions of links and shackles are to be in accordance with Ch 10 Equipment for Mooring and Anchoring or the Rules for the Manufacture, Testing and Certification of Materials and/or with the following International Standards;

- ISO 1834: *Short link chain for lifting purposes – General conditions of acceptance*;
- ISO 1835: *Round steel short link chains for lifting purposes – Medium tolerance sling chains – Grade 4, stainless steel*;
- ISO 1836: *Short link chain for lifting purposes – Grad M (4), calibrated, for chain hoists and other lifting appliances*;
- ISO 1704: *Ships and marine technology – Stud link anchor chains*, or
- DIN 766A

5.10 Correction of required minimum mass

5.10.1 Where the maximum current expected in service considerably exceeds 8 km/h, the anchor mass required by *Pt 3, Ch 12, 5.4 Bow anchors 5.4.1* or *Pt 3, Ch 12, 5.4 Bow anchors 5.4.2* is to be increased by the factor:

$$\left(\frac{\text{current speed, in km/hr}}{8}\right)^{1,875}$$

5.10.2 Where the maximum current expected in service is less than 8 km/h, the anchor mass required by *Pt 3, Ch 12, 5.4 Bow anchors 5.4.1* or *Pt 3, Ch 12, 5.4 Bow anchors 5.4.2* may be reduced by the factor:

$$\left(\frac{\text{current speed, in km/hr}}{8}\right)^{0,5}$$

5.10.3 The reduction allowed by *Pt 3, Ch 12, 5.10 Correction of required minimum mass 5.10.2* does not apply for ships which need to comply with *Pt 3, Ch 12, 5.1 Scope 5.1.4*.

5.11 Testing of equipment

5.11.1 All anchors and chain cables are to be tested at establishments and on machines recognised by the Committee and under the supervision of LR's Surveyors or other Officers recognised by the Committee, and in accordance with *Ch 10 Equipment for Mooring and Anchoring* of LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

5.11.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be provided. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the ship.

5.11.3 For holding power testing requirements relating to High Holding Power anchors, *see Ch 10, 1.8 Super high holding power (SHHP) anchors* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

5.11.4 For special anchors, proof tests are to be carried out in accordance with *Ch 10, 1.8 Super high holding power (SHHP) anchors* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* where the proof test load for the anchor is to be determined as follows;

$$\text{proof test load (special)} \frac{25}{\text{\% mass reduction of special anchor}} \times \text{proof test kN}$$

See also Pt 3, Ch 12, 5.7 Special anchors 5.7.2.

5.11.5 Steel wire and fibre ropes are to be tested as required by *Ch 10 Equipment for Mooring and Anchoring* of LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

5.11.6 For ships certified in accordance with the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN), a certificate in accordance with European Standard EN 10 204 *Metallic Products* shall be kept on board for the required towlines and mooring lines.

5.12 Anchors' general requirements

5.12.1 Anchors are to be of an approved design and of a type suitable for the intended service. The design of all anchor heads is to be such as to minimise stress concentrations and, in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.12.2 The mass of the head, including pins and fittings, of an ordinary stockless anchor is to be not less than 60 per cent of the total mass of the anchor.

5.12.3 The use of cast iron anchors is prohibited.

5.13 Towlines and mooring lines

5.13.1 Ships with an overall length not less than 20 m shall be equipped with at least 3 mooring lines. Their lengths are to be in accordance with *Table 12.5.5 Required length of mooring lines*.

Table 12.5.5 Required length of mooring lines

Item	Requirement
1st Line	$L_{m1} = L_{oa} + 20$ but need not be greater than 100 m
2nd Line	$L_{m2} = 2/3\ L_{m1}$
3rd Line	$L_{m3} = 1/3\ L_{m1}$
L_{m1}, L_{m2}, L_{m3} = required length of respective mooring line, in metres	
The 3rd line need not be fitted on ships having a length less than 20 m	

5.13.2 The required breaking strength of the mooring lines is to be in accordance with *Table 12.5.6 Required breaking load of mooring*.

Table 12.5.6 Required breaking load of mooring

For ships where	Requirement
$L_{oa} \times B_e \times T_e \leq 1000$	$R_s = 60 + 0{,}1\,(L_{oa} B_e T_e)$
$L_{oa} \times B_e \times T_e > 1000$	$R_s = 150 + 0{,}01\,(L_{oa} B_e T_e)$
R_s = minimum breaking load, in kN	

5.13.3 Tugs intended for towing shall be equipped with a number of towlines suitable for the intended service. The main towline shall have a length of at least 100 m and shall have a breaking load, in kN, not less than one third of the total power, in kW, of the main engine(s).

5.13.4 Motor ships and pushers intended for towing shall be equipped with a towline having a length of at least 100 m and a breaking load, in kN, not less than one quarter of the total power, in kW, of the main engine(s).

5.13.5 Towlines and mooring lines may be of wire, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre towlines are to comply with the requirements of *Ch 10 Equipment for Mooring and Anchoring* of LR's Rules for Materials.

5.13.6 Attention is drawn to the requirements of the ADN where it is required that tankers of Type G, C and N are being moored with steel wires during loading and discharging.

5.13.7 Means are to be provided to enable mooring lines to be efficiently secured on board ship by an adequate number of suitably placed bollards on either side of the ship.

5.14 Windlasses

5.14.1 The requirements of *Pt 3, Ch 12, 5.9 Chain cables 5.9.3* apply equally to bow and stern anchor winches.

5.14.2 On ships equipped with anchors having a mass of over 50 kg, windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements for anchor davits will be specially considered.

5.14.3 The windlasses may be hand or power-operated. Hand operated windlasses are only acceptable if the effort required at the handle does not exceed 15 kgf for raising one anchor at a speed of not less than 2 m/min and making about 30 turns of the handle per minute.

5.14.4 The capability of the power-operated windlass to break out and raise the anchor at a mean speed of not less than 9 m/min is to be proven during the trials.

5.14.5 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

5.15 Structural requirements

5.15.1 The windlass or winch is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be adequate for the loads imposed by the winch. The supporting structure for the anchor windlass is to be adequate for the greater of the brake holding load and a load equal to 45 per cent of the Rule breaking load of the cable passing over them. The structural design integrity of the bedplate is the responsibility of the Shipbuilder and windlass or winch manufacturer.

5.15.2 Where cables pass through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the possibility of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them. The supporting structure is to be adequate for these loads.

5.15.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary. In case a bulbous bow has been fitted, reinforcing is also to be arranged in way of those parts of bulbous bows liable to be damaged by anchors or cables. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses.

5.15.4 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

5.15.5 Where means of access is provided to the chain locker, it is to be closed by a substantial cover and secured by closely spaced bolts.

5.15.6 Chain lockers and spurling pipes are to be watertight up to the exposed weather deck and the space is to be efficiently drained. However, bulkheads between separate chain lockers, or which form a common boundary of chain lockers, need not be watertight.

5.15.7 Provision is to be made for securing the bitter end of the chain cable to the ship structure. The fastening for securing the bitter end is to be capable of withstanding a force of not less than 15 per cent and not greater than 30 per cent of the minimum breaking strength of the as fitted chain cable. It is to be provided with suitable means such that, in case of emergency, the chain cable may be easily slipped to sea from an accessible position outside the chain cable locker. Where the mechanism for slipping the chain cable to sea penetrates the chain locker bulkhead, this penetration is to be made watertight.

5.15.8 Alternatively the cable end connection may be accepted where it has been designed and constructed to a recognised National or International Standard.

5.15.9 The cable clench supporting structure is to be adequately stiffened in accordance with the breaking strength of the fastening provided.

5.15.10 When wire rope instead of chain is used for the anchor cable, it is to be stored on a suitably designed drum or reel. Fairleads intended for use with wire rope cable are to be designed to minimise wear and to avoid kinking or other damage occurring to the rope.

Section
1 General requirements

■ Section 1
General requirements

1.1 General description

1.1.1 A elevating wheel-house system generally consists of several concentrically mounted slidable columns with the wheel-house fitted on the top of the innermost column, *see Figure 13.1.1 General sketch elevating wheel-house*. The number of columns normally varies between 2 and 4. The columns are usually square or rectangular. The wheel-house can be moved up and down by means of one or more (hydraulic) lifting cylinder(s) to reach the desired height. Another configuration may consist of a wheel-house fitted on a scissor lift, *see Figure 13.1.2 Scissor lift*, or may consist of a wheel-house suspended by hydraulic jacks. This Chapter mainly deals with elevating wheel-house systems of the type with the slidable columns. Other systems will be specially considered.

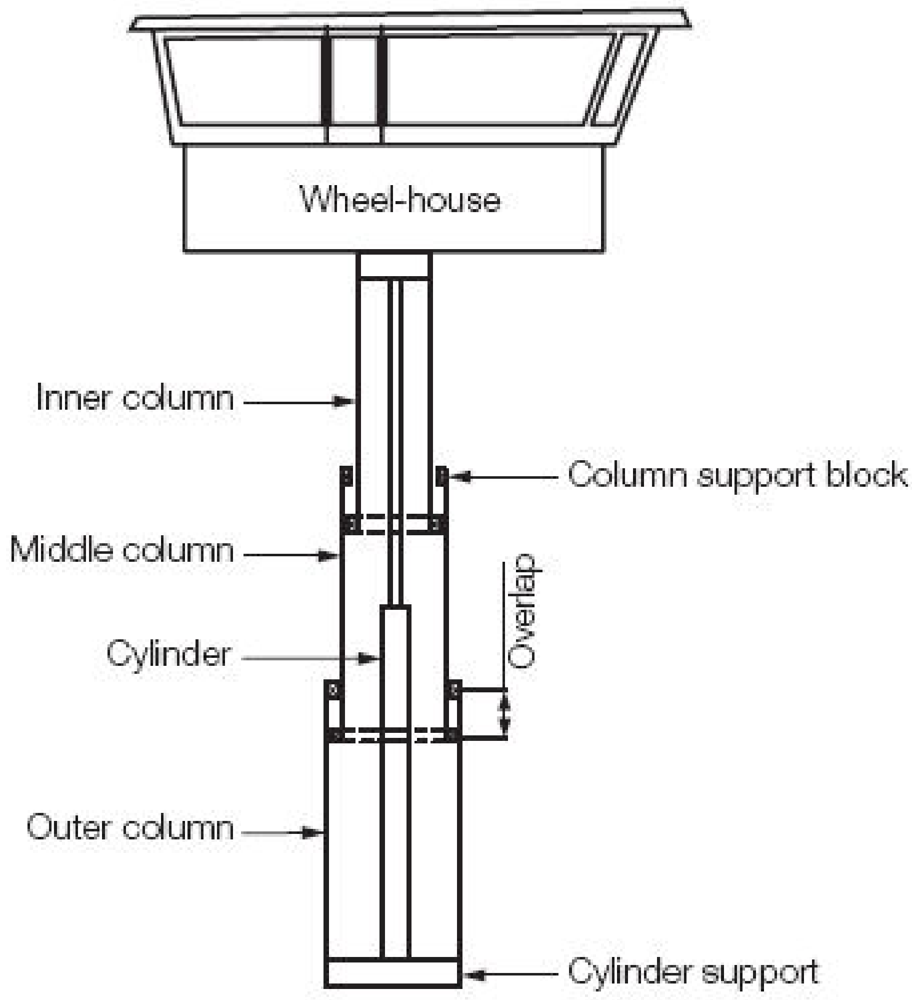


Figure 13.1.1 General sketch elevating wheel-house

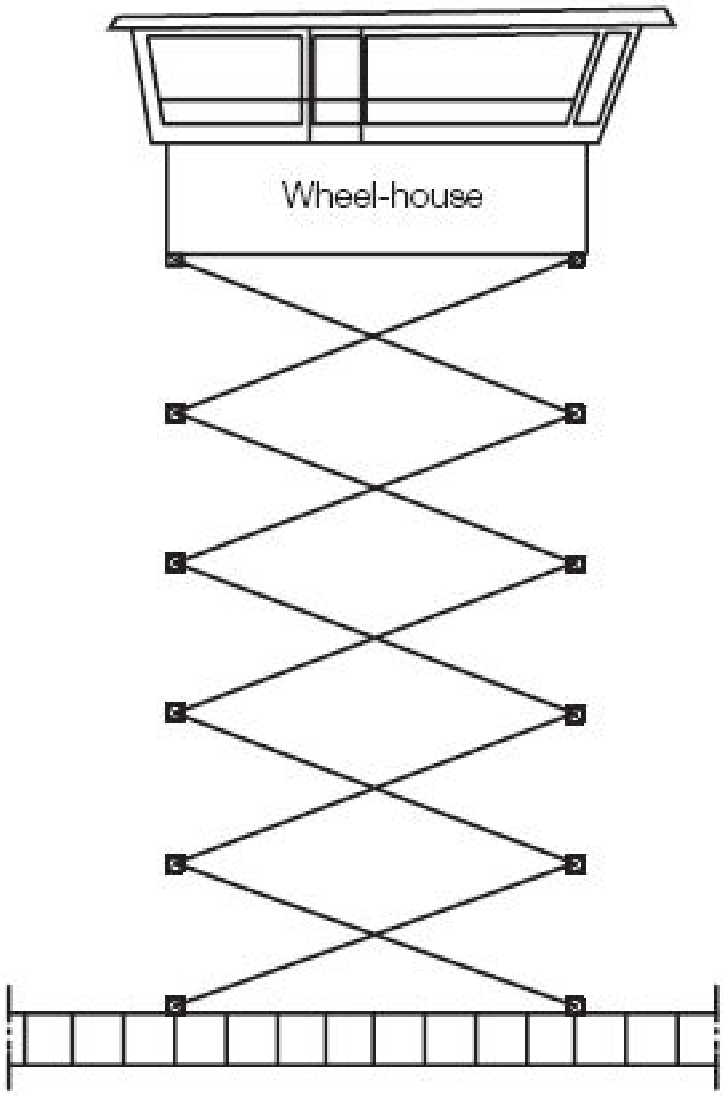


Figure 13.1.2 Scissor lift

1.1.2 The forces between the columns are transferred by support/sliding blocks, here after referred to as blocks.

1.1.3 The elevating wheel-house columns may be integrated into the ship's structure as follows:

(a) The outer column is fully integrated with the (flexible mounted) deck-house, see *Figure 13.1.3 Wheel-house configuration 1*. In this case one or more pillars may need to be fitted underneath the outer column for additional vertical support. In cases where the deck-house is flexibly mounted on vibration mounts vibration mounts will also need to be fitted between the column and the additional pillar(s).

(b) The outer column is integrated in the (flexibly mounted) deck-house and is continued up to the bottom construction of the ship, *see Figure 13.1.4 Wheel-house configuration 2*. In cases where the deck-house is flexibly mounted on vibration mounts the outer column will need to be mounted on vibration mounts in way of the bottom structure as well.

(c) The outer column is independent of the flexibly mounted deck-house and directly fitted onto the bottom construction of the ship, *see Figure 13.1.4 Wheel-house configuration 2*. In this case the columns are fully integrated with the ship's structure and it may be desired to mount the wheel-house on vibration mounts at the connection with the top of the innermost column in order to isolate it from vibrations generated within the ship.

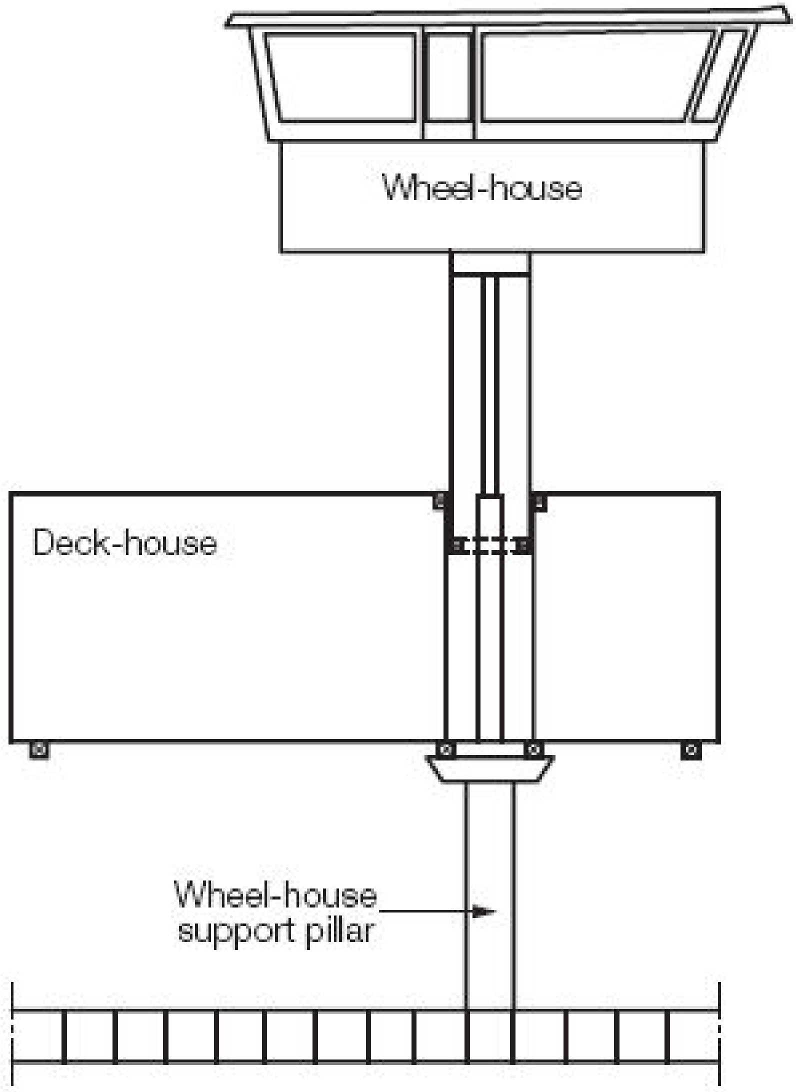


Figure 13.1.3 Wheel-house configuration 1

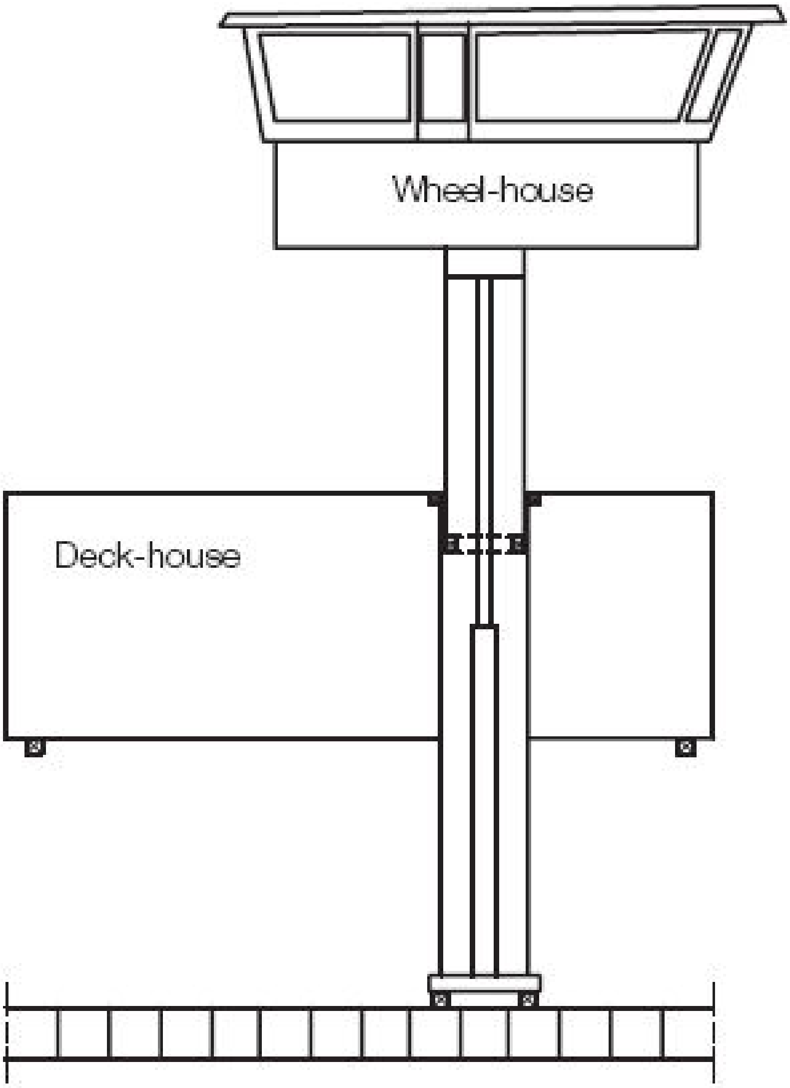


Figure 13.1.4 Wheel-house configuration 2

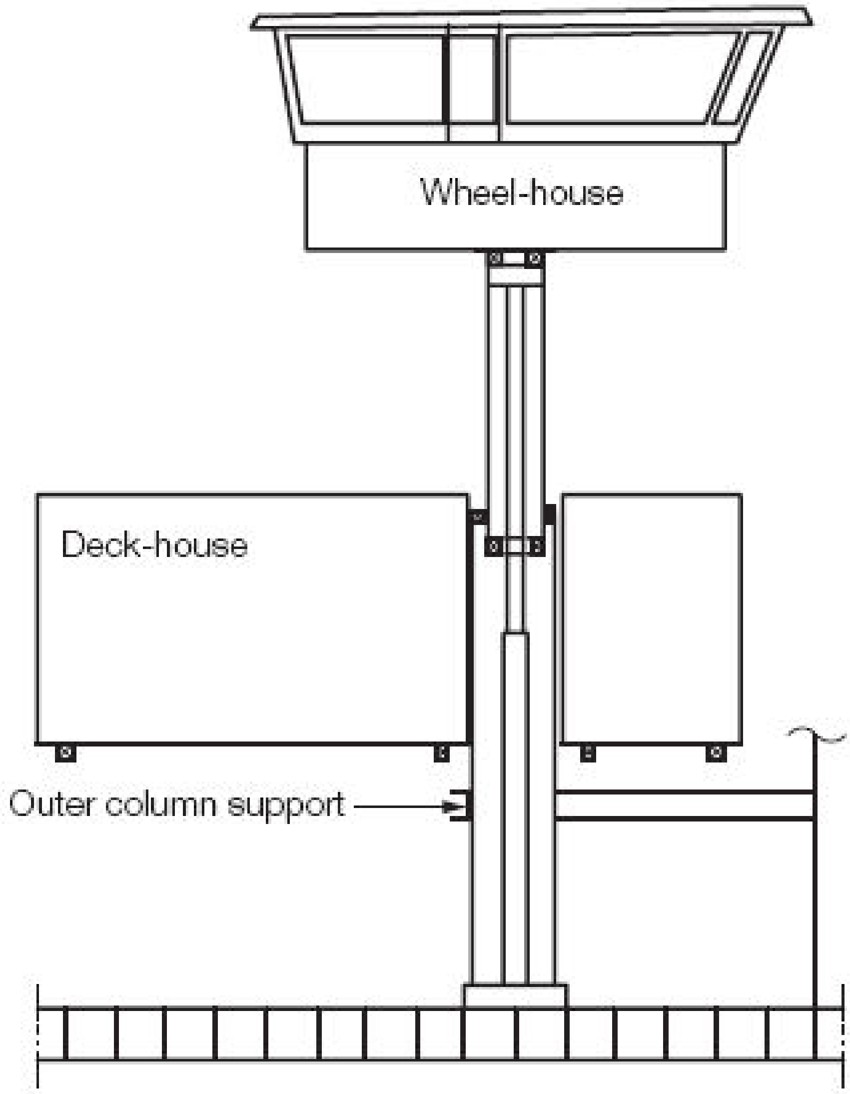


Figure 13.1.5 Wheel-house configuration 3

1.1.4 In the case of the elevating wheel-house being arranged with columns (*see Figure 13.1.3 Wheel-house configuration 1*), the bottom structure of the wheel-house should consist of 4 main girders fitted in line with the inner column plating and forming a cross of a pair of beams. The ends of the girders in way of the wheelhouse external walls can be considered as 'free' whilst the girders can be considered as 'clamped' in way of the inner column plating. The primary bottom structure should therefore be considered as being built of eight girders clamped at one side (at the inner column). *See Figure 13.1.6 Primary floor girders*.

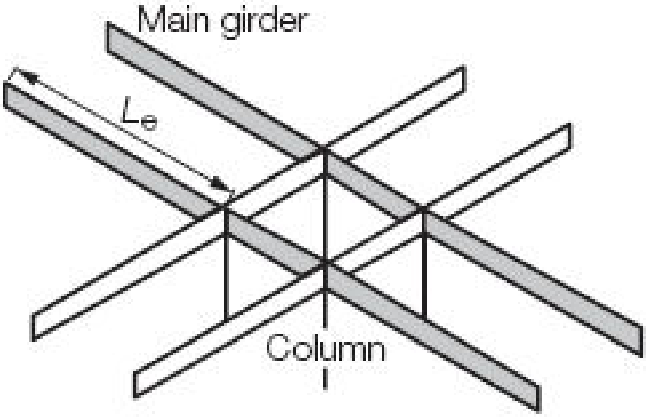


Figure 13.1.6 Primary floor girders

1.2 General requirements

1.2.1 Elevating wheel-house systems are to be made of steel or aluminium and are to be adequately supported. The materials used are to comply with the applicable requirements stated in the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

1.2.2 The wheel-house is to be capable of supporting its own weight, including all equipment, and the maximum number of persons allowed in the wheel-house simultaneously. A noticeplate in way of the entrance of the wheel-house should be fitted stating the maximum number of persons allowed in the wheel-house. The total mass corresponding with the number of people allowed should also be indicated. These figures are to be designated by the manufacturer. A minimum average weight of 75 kg per person is to be taken into account. Further specific design loads are given in *Table 13.1.1 Design loads on columns and wheel-house* and *Table 13.1.2 Design loads on wheel-house floor and roof*.

Table 13.1.1 Design loads on columns and wheel-house

Type load	Condition	
	Normal (transverse heeling)	Collision on the blow
Wind	p_w = 0,150 tonf/m^2	p_w = 0,010 tonf/m^2
Heel	10° static	—
Acceleration	—	0.5g

Table 13.1.2 Design loads on wheel-house floor and roof

Item	Load (kN/m^2)
Floor	p_{floor} = 3,18
Gallery or walkway around wheel-house	p_{walk} = 2,12
Roof	p_{roof} = 1,0

1.2.3 The columns are to be capable of withstanding loads induced by heeling or rolling of the ship as well as loads induced by a collision.

1.2.4 The blocks are to be capable of transferring the loads transferred by the columns.

1.2.5 The hydraulic cylinder(s) is/are to be capable of supporting the wheel-house, the number of columns connected, and the specified number of persons in the wheelhouse, taking into account a dynamic factor of 1,20 on the static load.

1.2.6 The hydraulic cylinder(s) is/are to be of an approved type.

1.2.7 The cylinder support constructed in the bottom of the outer column is to be capable of withstanding the loads imposed by the hydraulic cylinder including its own weight and the dynamic factor mentioned in *Pt 3, Ch 13, 1.2 General requirements 1.2.5*.

1.2.8 Attention is drawn to *Pt 5, Ch 18 Elevating Wheelhouse Systems* regarding machinery aspects and *Pt 6, Ch 1 Control Engineering Systems* in respect of electrical and control engineering aspects.

1.2.9 When the proposed construction of the elevating wheel-house system differs from the general design as detailed in *Pt 3, Ch 13, 1.1 General description 1.1.1*, *Pt 3, Ch 13, 1.1 General description 1.1.3* and *Pt 3, Ch 13, 1.1 General description 1.1.4*, it will be subject to special consideration.

1.2.10 The elevating wheel-house system is to be operated by the ship's crew only after complete installation and appropriate instructions by the manufacturer and final acceptance by Lloyd's Register.

1.3 Design loads and columns forces

1.3.1 The design loads on the columns, blocks and cylinder support, if applicable, are given in *Table 13.1.1 Design loads on columns and wheel-house*. The design loads given in *Table 13.1.1 Design loads on columns and wheel-house* apply to ships navigating in Zone 3. For ships having the notation Zone 1 or Zone 2 in their Class Notation, the design loads are given in *Pt 3, Ch 13, 1.7 Service in Zones 1 and 2* .

1.3.2 The design loads for the construction of the wheelhouse are given in *Table 13.1.2 Design loads on wheel-house floor and roof* and are applicable to ships navigating in all zones.

1.3.3 The design bending moment and shear forces of the main girder at the clamping in way of the column is to be determined as outlined in *Table 13.1.3 Determination of bending moment and shear force in main girder of wheel-house foundation*. Actual bending moments, shear forces and stresses may also be determined by direct calculations taking account of actual lengths and relative stiffnesses of the girders.

Table 13.1.3 Determination of bending moment and shear force in main girder of wheel-house foundation

Item	Parameter	Requirement
Maximum bending moment in main girder	*BM*	$\left(\frac{1}{6}q_1 + \frac{1}{3}q_2\right)b^2 + Pa$ kNm
Maximum shear force in main girder	*SF*	$\frac{1}{2}\left(q_1 + q_2\right)b + P$ kN
Symbols		

q_1 = $\dfrac{p_{floor} s_1}{1000}$ kN/m

q_2 = $\dfrac{p_{floor} s_2}{1000}$ kN/m

s_1 = spacing of main girder in way of clamping, in mm, *see also Figure 13.1.9 Definition S $_1$ and S $_2$*

s_2 = spacing of main girder at end, in mm, *see also Figure 13.1.9 Definition S $_1$ and S $_2$*

a = distance from inner column to wheel-house side plating, in metres

b = distance from inner column to end of girder, in metres (= a in case of wheel-house without gallery)

P = $\dfrac{p_{roof} Area_{roof}}{n}$ in kN/m

n = number of main girders (generally 8)

p_{roof} = as defined in *Table 13.1.2 Design loads on wheel-house floor and roof*, in kN/m^2

$Area_{roof}$ = area of roof, in m^2

Note For clarification, *see also* Figs. *Figure 13.1.7 Load case elevating wheel-house*, *Figure 13.1.8 Load case elevating wheel-house with walkway* and *Figure 13.1.9 Definition S $_1$ and S $_2$* .

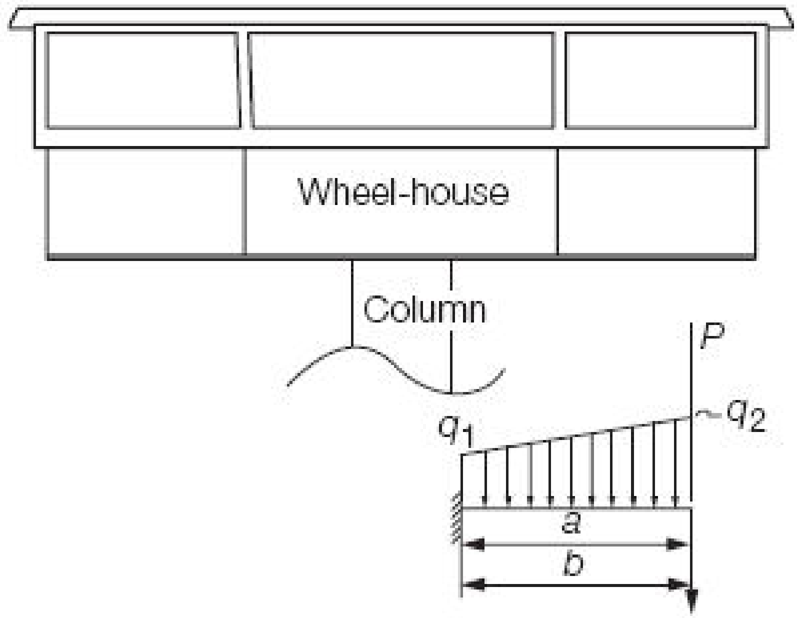


Figure 13.1.7 Load case elevating wheel-house

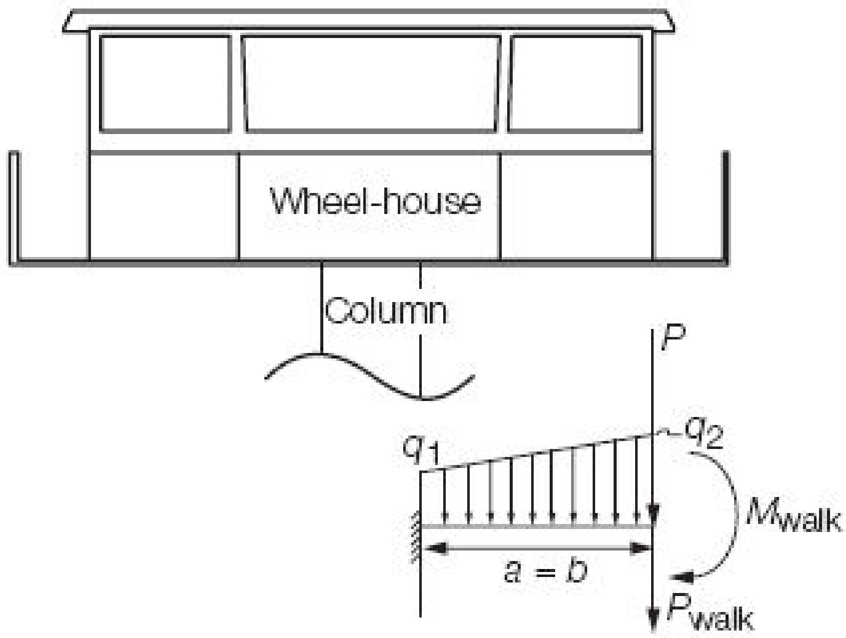


Figure 13.1.8 Load case elevating wheel-house with walkway

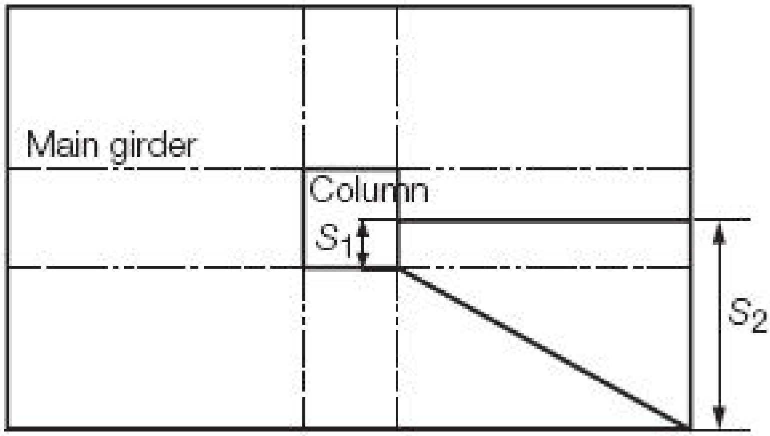


Figure 13.1.9 Definition S_1 and S_2

1.3.4 The column forces are the reaction forces resulting from the following:

- Loads due to the static heeling (Zone 3) or dynamic rolling (Zones 1 and 2) of the ship.
- Loads induced by a collision.
- Wind loads.

The method of calculation of these forces on the blocks is given in *Table 13.1.4 Block force*. *Table 13.1.4 Block force* is based on the assumption that the longitudinal and transverse centre of gravity of the system is approximately at the centre of the columns. If this is not the case the effects are to be taken account of by further direct calculations.

Table 13.1.4 Block force

Load	Requirement
Design horizontal load, F	$\sum_{i}^{n}\left[A_{\mathrm{i}}p_{\mathrm{w}} + \zeta\, m_{\mathrm{i}} + F_{\mathrm{roll,\,dyn,\,i}}\right]$ tonf
Design bending moment, M	$\sum_{i}^{n}\left[A_{\mathrm{i}}p_{\mathrm{w}}h_{\mathrm{wi}} + \left(\zeta\, m_{\mathrm{i}} + F_{\mathrm{roll,\,dyn,\,i}}\right)h_{\mathrm{mi}}\right]$ tonf
Upper block force R_{upper}, per block	$\frac{1}{2}\left(\frac{M}{overlap} + F\right)$tonf
Lower block force R_{lower}, per block	$\frac{M}{2\ overlap}$ tonf
Symbols	

A_i	=	projected area of part i of the elevating wheel-house system, perpendicular to the wind direction, in m_2
h_{wi}	=	distance of the centre of area A_i up to upper block, in metres
m_i	=	mass of part i of the elevating wheel-house system, in ton
h_{mi}	=	distance of the centre of gravity of part i of the elevating wheel-house system up to upper block, in metres
$F_{roll,dyn,i}$	=	transverse component of dynamic roll, only applicable when sailing in Zone 1 or 2, *see Pt 3, Ch 13, 1.7 Service in Zones 1 and 2*
n	=	total number of parts of the elevating wheel-house system, including the wheel-house, excluding the column of the upper block under consideration and columns below, *see also* Note 1
p_w	=	wind pressure, *see Table 13.1.1 Design loads on columns and wheel-house*
ζ	=	sin φ for heeled or rolling conditions; = 0,50 for collisions
φ	=	10° for Zone 3, 15° for Zone 2, 20° for Zone 1, *see also Pt 3, Ch 13, 1.7 Service in Zones 1 and 2*
overlap	=	distance between lower blocks of a column and the upper blocks of the column below when the wheelhouse is in the outmost lifted position, *see also* Note 2

Note 1. *See also* Figs. *Figure 13.1.10 Overview support/sliding blocks* for an example of n = 4

Note 2. The required minimum overlap depends on the allowable forces. The following values could be used as a recommendation in the initial design stage:
overlap ≈ 1 x maximum width of outer column for services in Zone 3,
overlap ≈ 1,2 x maximum width of outer column for services in Zone 2, and
overlap ≈ 11/2 x maximum width of outer column for services in Zone 1 for the determination of the overlap between the outer column and the lowest middle column.

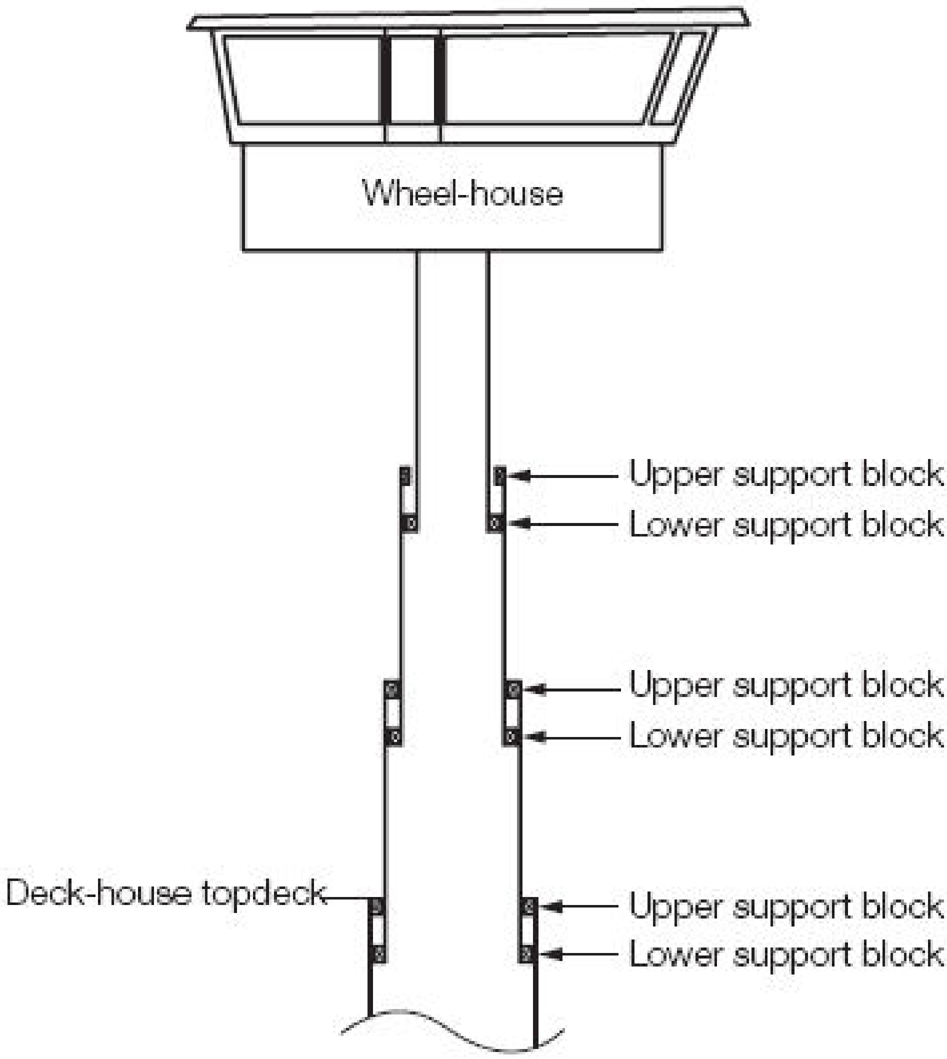


Figure 13.1.10 Overview support/sliding blocks

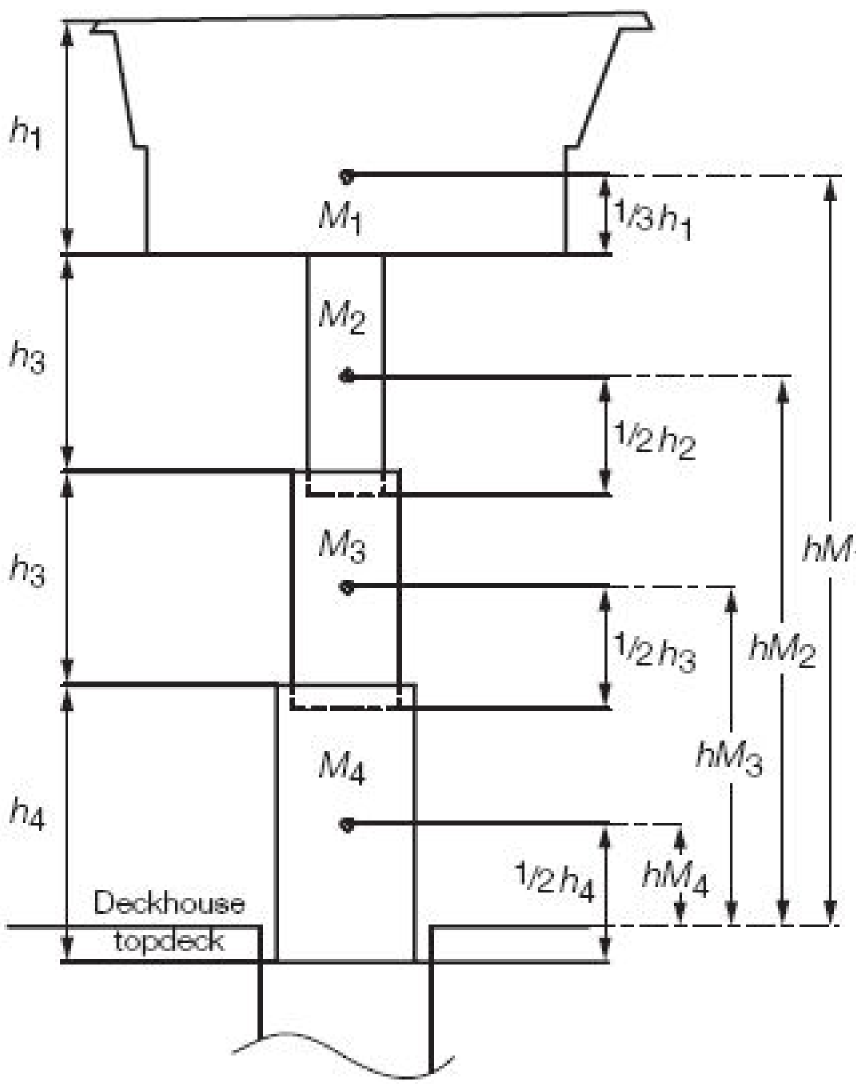


Figure 13.1.11 Mass forces

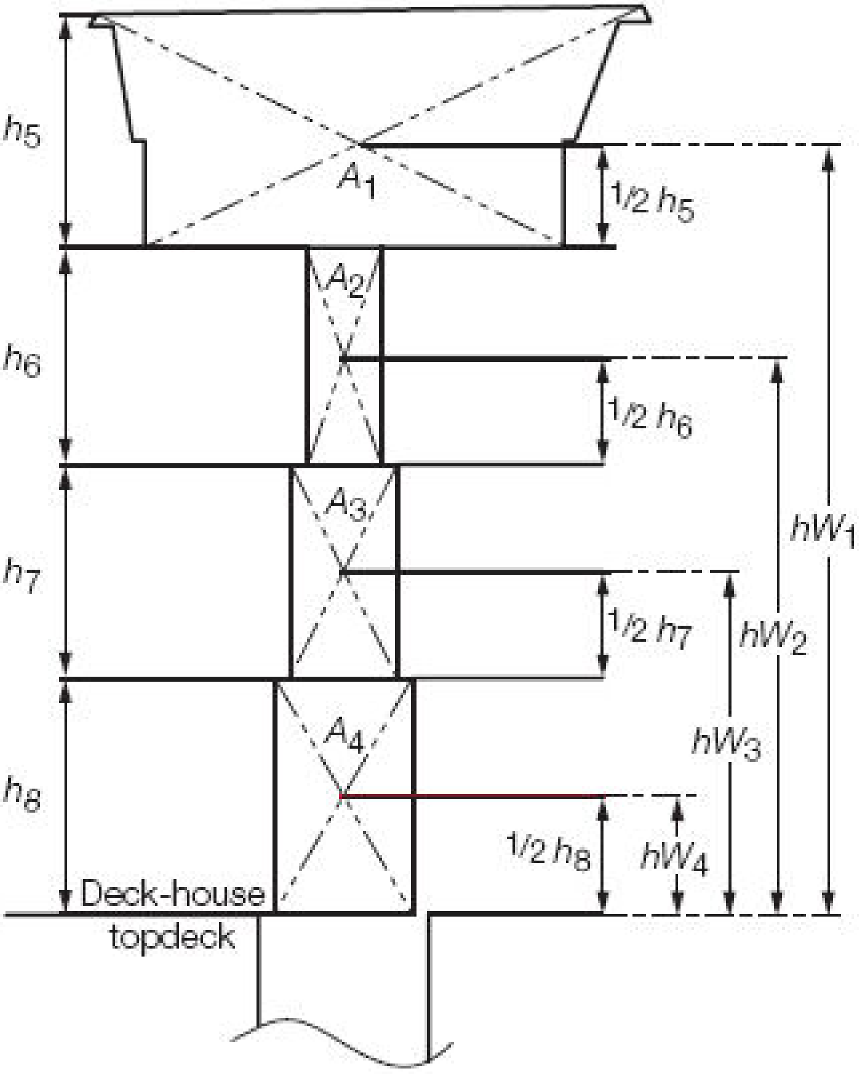


Figure 13.1.12 Wind forces

1.4 Structural requirements

1.4.1 Where the outer column is integrated in the deckhouse (building methods in accordance with *Figure 13.1.3 Wheel-house configuration 1* and *Figure 13.1.4 Wheel-house configuration 2*) the upper blocks of the outer column are to be in line with the topdeck of the deck-house. Provisions are to be made for an efficient and adequate distribution of loads into this deck. A buckling analysis of the topdeck plating in way may be required. If necessary, anti-buckling strips are to be fitted. Preferrably, the side plating of the outer column is to be arranged in line with the beams and girders in the top and lower deck of the deck-house. Where deck girders and beams are not in line, brackets are to be fitted in line with the column side plating connecting the outer column with the beams and girders in the deck-house.

1.4.2 Where the outer column is independent from the flexibly mounted deck-house and directly fitted on to the single or double bottom construction of the ship, provision is to be made to support the outer column at a distance as large as possible above the top of the bottom structure but not less than 2,0 m. These supports, consisting of heavy beams efficiently connected to the ship's supporting structure, are to be provided in the horizontal transverse and longitudinal direction of the ship in order to provide additional transverse and longitudinal support. In this way the occurrence of high bending moments induced by the outer column on the bottom structure is to be prevented.

1.4.3 The number, type and position of vibration mounts or so called flexibles are dependent on the type of mount, the weight of the elevating wheel-house, the method of building in and the amount of weight of the deck-house that is supported by the outer column. The vibration mounts should be of an approved type and should be installed in accordance with the manufacturer's recommendations.

1.4.4 If the cylinder support in the bottom of the outer column consists of an **I**-shaped beam, anti tripping brackets are to be placed on the beam in way of the cylinder. Tripping brackets are also to be placed on the beam in line with the vibration mounts below.

1.4.5 Items such as safety pins, axles, brackets, etc. are to be designed for the loads imposed on them including the appropriate dynamic factors using the allowable stresses as provided in *Table 13.1.8 Safety factors on yield or 0,2 per cent proof stress*.

1.5 Wheel-house

1.5.1 In this Section, only requirements for the construction of the bottom structure of the wheel-house are given. The construction of the side walls and roof is to be carried out in accordance with good shipbuilding practice in line with the Builder's procedures and standards.

1.5.2 The main girders are defined as primary members. Other beams and stiffeners are defined as secondary members.

1.5.3 The connection of the main girders to the inner column is to be such that these can be considered as clamped. Accordingly, the web of the main girder is to be in line with the plating of the inner column. (Double) continuous welding is required.

1.5.4 The effective plate width of the attached cover plating on the bottom side of the wheel-house foundation is to be determined in accordance with*Pt 3, Ch 3, 3 Structural idealisation*, with the factor *f* to be divided by 2. The effective width of a plate attached to the main girder is then calculated as follows:

$$b_{\mathrm{eff}} = \frac{1}{2} f b$$

1.5.5 The number of holes in the main girders is to be kept to a minimum. Holes are not allowed in the main girder in way of the connection to the inner column. Generally, a minimum of 1,50 times the web depth of the main girder under consideration is required between the edge of a hole and the inner column.

1.5.6 Openings in beams are to have well rounded corners. The diameter or height of any opening should not exceed half the depth of the web of the beam. For rectangular openings, the length of the opening is limited to 65 per cent of the web height. The distance between openings should generally not exceed 75 per cent of the diameter or length of the opening

1.5.7 Where larger holes are proposed, these are subject to special consideration and reinforcements by means of double plates or flanges having increased properties are required to compensate the loss of material.

1.5.8 The wheel-house is to be capable of being closed gastight when installed on dry cargo ships carrying dangerous goods in large quantities or on tankers carrying dangerous goods. *See Pt 4, Ch 1, 12 Additional requirements for ships carrying dangerous goods* and *Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk* respectively.

1.5.9 In case of a gallery or walkway partly or totally being fitted around the wheel-house, extra attention is to be paid to its supporting arrangement. It is to be ensured that the beams are in line with local beams or main girders fitted in the wheel-house and are well clamped without the presence of any hard spots.

1.5.10 The stresses in the main girders of the wheel-house foundation can be calculated as stated in *Table 13.1.5 Stresses in main girders of wheel-house*.

Table 13.1.5 Stresses in main girders of wheel-house

Item	Parameter	Requirement
Bending Stress	σ_b	$\frac{BM}{Z}$ 1000 N/mm^2
Shear stress	τ	$\frac{SF}{A_W}$ 1000 N/mm^2
Symbols		

BM = max bending moment acc. to *Table 13.1.3 Determination of bending moment and shear force in main girder of wheel-house foundation*

SF = max shear force acc. to *Table 13.1.3 Determination of bending moment and shear force in main girder of wheel-house foundation*

Z = section modulus of main girder under consideration, in cm^3

A_W = web area of main girder under consideration, in mm^2

1.5.11 The stresses in the other beams can be calculated as stated in *Table 13.1.6 Stresses in secondary members of wheel-house*.

Table 13.1.6 Stresses in secondary members of wheel-house

Item	Parameter	Requirement
Bending stress	σ_{bl}	$\varphi_Z \frac{psl^2}{Z}$ 1000 N/mm2
Shear stress	τ_1	$\varphi_A \frac{psl}{A_w}$ 1000 N/mm^2
Symbols		

φ_Z = section modulus coefficient, to be taken as 0,1 for secondary members where the end fixity of both ends is considered to be partial; to be taken as 0,5 for cantilever beams (as for the beam in the gallery)

φ_A = web area coefficient, to be taken as 0,5 for secondary members where the end fixity of both ends is considered to be partial; to be taken as 1 for cantilever beams (as for the beam in the gallery)

p = p_{floor} or p_{walk} as applicable as defined in *Table 13.1.2 Design loads on wheel-house floor and roof*

s = stiffener spacing, in mm

l = length of stiffener, in metres

Z = section modulus of stiffener, in cm^3

A_W = web area of stiffener, in mm^2

1.5.12 The stresses as calculated in *Table 13.1.5 Stresses in main girders of wheel-house*and *Table 13.1.6 Stresses in secondary members of wheel-house* are to be lower than the allowable stresses as given in *Pt 3, Ch 13, 1.8 Allowable stresses*.

1.6 Columns

1.6.1 The thickness of the column plating is to be determined for each column. Parameters are the reaction forces in the blocks and the design bending moment in the columns. The thickness of the plating of the outer column is to be equal to the thickness of the lowest middle column (or inner column in the case of the total number of columns is 2). The minimum thickness, t_p is to be taken as the greater of t_{p1} and t_{p2}:

$$t_{p1} = \sqrt[3]{\frac{5964 fos F_{block}\ b_{c1}}{E}}\ \text{mm}$$

$$t_{p2} = \frac{9,81M}{sf\ b_{c1} b_{c2}\ \sigma_0} \times 10^6 \text{mm}$$

where

t_p = plating thickness of column under consideration, in mm, to be ≥ 8 mm for steel plating and ≥ $\sqrt{k}$ 8 mm for aluminium alloys

k = material factor $\frac{235}{\sigma_0}$

σ_0 = yield stress of the used plating material or the 0,2 per cent proof stress (in the welded condition), in N/mm^2

fos = factor of safety with respect to buckling aspects; to be taken as 1,2 for normal (rolling) conditions and 1,0 for collision condition

f_{block} = reaction force in upper block of the column below, in tonf, = R_{upper} as calculated in accordance with *Table 13.1.4 Block force* and, if applicable, Table *Table 13.1.7 Determination of transverse forces of each individual componet of the elevating wheel-house system in Zones 1 and 2* , either in transverse or longitudinal direction

E = modulus of elasticity of material, in N/mm^2

b_{c1} = breadth of column under consideration, in mm, measured in the direction of F_{block}

b_{c2} = breadth of column under consideration, in mm, measured perpendicular to the direction of F_{block}

M = design bending moment, in tonfm, as calculated in accordance. with *Table 13.1.4 Block force* and, if applicable, *Table 13.1.7 Determination of transverse forces of each individual componet of the elevating wheel-house system in Zones 1 and 2*

sf = safety factor for axial stresses, *see Table 13.1.8 Safety factors on yield or 0,2 per cent proof stress*.

Table 13.1.7 Determination of transverse forces of each individual componet of the elevating wheel-house system in Zones 1 and 2

Item	Requirement
Wind pressure, p_w	0,038 tonf/m^2
Roll period, T_r	$0,7\frac{B}{\sqrt{GM}}$, s to be taken as 6 if GM is unknown
Transverse component of static roll, $F_{roll, static, i}$, of the part i of the elevating wheel-house system, *see also* Note 1	$\zeta\ m_i$, *tonf*

Transverse component of dynamic roll, $F_{roll, dyn, i}$, of the 0,07024 mi zi, tonf part i of the elevating wheel-house system, *see also* Note 2	0,07024 mi $\frac{\varphi}{T_r^2}$ z_i, tonf
Symbols	
m_i = mass of the part i of the elevating wheel-house system, in tonf z_i = distance (perpendicular to deck) of centre of gravity of the part i to ship's centre of gravity, metres ζ = $\sin_\varphi$ φ = max roll angle of the ship, in degrees, to be taken as: For Zone 1 service: 20° if the actual heeling angle is unknown For Zone 2 service: 15° if the actual heeling angle is unknown B = breadth of ship, in metres GM = metacentre height of ship, in metres	
Note 1. The $F_{roll, static, i}$ is the mass component in the determination of F and M in *Table 13.1.4 Block force*. **Note** 2. The $F_{roll, dyn, i}$ is the dynamic component in the determination of F and M in *Table 13.1.4 Block force*. **Note** 3. Due to the different ship's sailing conditions, the rolling conditions may differ for each individual sailing condition. Therefore the transverse forces on the columns are at least to be calculated for the two main sailing conditions, i.e. the full load condition and the ballast condition. **Note** 4. Zones 1, 2, and 3 are defined in *Pt 1, Ch 2, 2.2 Character symbols 2.2.1*.	

1.6.2 Where the proposed thickness is not in accordance to the required thickness, a double plate may be fitted in line with the blocks to assure sufficient strength against buckling. The double plate should be such that the least moment of inertia of the two plates together, I_{comb}, has a minimum value of: $I_{comb} > \frac{f_{os}\, 497\, b_{c1}^2 F_{block}}{E}$ mm^4

taking into account an effective breadth of the column plating itself equal to the value of b_{c1}.

1.6.3 Generally, when a double plate is proposed, the dimensions *b x t* are to be as follows:

	proposed columns dimensions	proposed columns dimensions
breadth	b_c	$b = 0,3 \times b_c$
thickness	t_p	$t = t_p$

1.6.4 In view of potentionally high block forces the strength and means of attachment of the column plating in way of the blocks is to be specially considered and details of the blocks and plating in way are to be submitted for consideration.

1.7 Service in Zones 1 and 2

1.7.1 Elevating wheel-houses on ships intended to navigate in Zones 1 or 2 are to withstand both the normal loads, as calculated in accordance with *Table 13.1.4 Block force*, as well as the forces induced by rolling of the ship when sailing under increased conditions as for Zones 1 and 2. In this case the additional loads are to be calculated in accordance with *Table 13.1.7 Determination of transverse forces of each individual componet of the elevating wheel-house system in Zones 1 and 2* . The formulas in *Table 13.1.7 Determination of transverse forces of each individual componet of the elevating wheel-house system in Zones 1 and 2* should be applied to each individual component of the elevating wheel-house system. The total bending moment acting on the outer column and the resulting reaction forces of the blocks are to be calculated as outlined in *Table 13.1.4 Block force*. The allowable stresses are to be determined according to *Pt 3, Ch 13, 1.8 Allowable stresses*.

1.7.2 The Builder of the elevating wheel-house system is to be provided with proper values of the hydrodynamic and hydrostatic parameters *B*, *GM*, and *f*.

1.7.3 When T_r and f are known through ship measurements or detailed analysis, these values are to be used in the calculation of *Table 13.1.7 Determination of transverse forces of each individual componet of the elevating wheel-house system in Zones 1 and 2* .

1.8 Allowable stresses

1.8.1 The safety factors listed in *Table 13.1.8 Safety factors on yield or 0,2 per cent proof stress* are the limiting stress coefficients to be multiplied with the yield stress or the 0,2 per cent proof stress of the material as applicable. Thus the allowable stress = safety factor x σ_o , with σ_o as defined in *Pt 3, Ch 13, 1.6 Columns*.

Table 13.1.8 Safety factors on yield or 0,2 per cent proof stress

Type of stress	Condition		
General Construction	Inland waterways- Normal conditions (Zone 3)	Zone 1 and Zone 2	Collision
Bending + normal, σ_x	0,60	0,75	0,90
Shear τ	0,42	0,53	0,64
Equivalent, σ_{eq}	0,75	0,85	1,0
Local stresses on safety pins, axles, brackets, etc.			
Axial	0,50	0,63	0,75
Shear	0,35	0,44	0,53
Equivalent	0,63	0,71	0,83
Note The bending and normal stresses are known as axial stresses.			

1.8.2 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + 3\tau^2}$$

1.9 Welding requirements

1.9.1 (Double) continuous welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Primary and secondary members to plating in way of end connections.
(b) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets.
(c) The cylinder supporting structure in the bottom of the outer column to the column plating.
(d) The connection of the main girders of the wheel-house foundation to the side plating of the inner column.
(e) Double plate on middle column if needed to fulfill buckling requirements.
(f) Double plate on cylinder support if needed to fulfill shear strength requirements.
(g) Anti-tripping brackets where high local loadings are imposed.

1.9.2 The throat thickness of the (double) continuous welds is to be 0,44 x t_p, with t_p being the least value of the plating thicknesses being joined. Full or deep penetration welding may be required where high local loadings are imposed.

1.10 Non structurally related items

1.10.1 The recommendations listed in this paragraph are non-Classification items and may be overruled or waived by different or additional requirements from the applicable National Authorities. It is however strongly recommended to implement these recommendations.

1.10.2 It is recommended to designate clearly and mark the area directly below the wheel-house as an area of non trespassing.

1.10.3 When the non trespass area as defined in *Pt 3, Ch 13, 1.10 Non structurally related items 1.10.2* should be trespassed for maintenance purposes or for other reasons, it is recommended that the elevating wheel-house is secured from moving up or down.

1.10.4 External stairs for access to the wheel-house are not a classification item. It is however strongly recommended to indicate clearly the number of persons that are allowed simultaneously on the stairs and for which the stairs have been approved by the relevant authority.

Contents

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to self-propelled ships with machinery aft and non-propelled ships (barges) towed and/or pushed or carried alongside another ship, designed primarily for the carriage of:

(a) general dry cargo; or
(b) containers; or
(c) bulk heavy dry cargoes (including ore) in holds;
(d) either type *Pt 4, Ch 1, 1.1 Application 1.1.1* or *Pt 4, Ch 1, 1.1 Application 1.1.1.(b)* and *Pt 4, Ch 1, 1.1 Application 1.1.1.(c)* type cargoes.

1.1.2 The structural requirements of this Chapter are intended to cover the midship region as defined in*Pt 3, Ch 3, 2.2 Definition of midship region* for ships having a length not exceeding 135 m, a ratio of length to depth generally not exceeding 35 and a ratio of breadth to depth not exceeding 5.

1.1.3 Arrangements and scantlings forward and aft of the midship region are to comply with *Pt 3, Ch 5 Fore End and Aft End Structure*and *Pt 3, Ch 6 Machinery Spaces* so far as applicable; the remaining requirements of Part 3 are also to be complied with as appropriate to the intended arrangements.

1.1.4 For ships intended to carry dangerous goods in higher quantities as listed in Part 7 of the ADNR/ADN, *see Pt 4, Ch 1, 12 Additional requirements for ships carrying dangerous goods*. This Section also provides general guidance on the applicability and contents of the ADNR/ADN.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a single deck hull with wide hatch openings and continuous hatch side coamings, a single or double skin arrangement in way of the cargo space and a single or double bottom arrangement. Consideration will be given to other arrangements.

1.2.2 Longitudinal or transverse framing may be adopted. Ships with a ratio of length to depth exceeding 25 or a length, *L*, over 70 m and having a double bottom, are generally to be constructed with longitudinal framing in the bottom. Alternatively, transverse framing may be adopted, provided suitable longitudinal stiffening is fitted to the bottom plating. If no double bottom is fitted, transverse framing with suitable longitudinal stiffening is, in general, to be applied.

1.2.3 The number and disposition of transverse bulkheads are to be as required by*Pt 3, Ch 7 Bulkheads*. Additional bulkheads may have to be fitted to provide for sufficient transverse strength of the vessel.

1.3 Class notation

1.3.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2, 2 Character of classification and class notations*.

1.3.2 Ships intended for the carriage of general cargoes in holds and on deck, with a loading equivalent to a stowage rate greater than 1,39 m^3/tonne, corresponding to a specific weight of cargo less than 0,72 tonne/m^3 and complying with the requirements of this Chapter will be eligible to be classed:

A1 I.W.W. Cargo Ship

or

A1 I.W.W. Cargo Barge

1.3.3 Ships intended for the carriage of general cargoes in holds and on deck, with a loading equivalent to a stowage rate greater than 1,39 m^3/tonne, corresponding to a specific weight of cargo less than 0,72 tonne/$m^3$and intended to carry containers and complying with the requirements of this Chapter will be eligible to be classed:

A1 I.W.W. Container Ship

or

A1 I.W.W. Container Barge.

1.3.4 Ships designed primarily for the carriage of bulk heavy dry cargoes (including ore) in holds, with a maximum specified stowage rate of 1,39 m^3/tonne, corresponding to a minimum specific weight of cargo 0,72 tonne/m^3 and complying with the requirements of this Chapter will be eligible to be classed:

A1 I.W.W. Bulk Carrier

or

A1 I.W.W. Bulk Carrier Barge.

1.3.5 Double hull ships built in compliance with Chapter 9, Section 9.1.0.80 of the ADN and complying with the additional requirements of *Pt 4, Ch 1, 12 Additional requirements for ships carrying dangerous goods* of this Chapter will be eligible to be classed:

DG

where DG stands for Dangerous Goods.

1.3.6 Where applicable, combinations of the above class notations may be assigned, i.e.:

A1 I.W.W. DG Container Ship/Bulk Carrier.

1.3.7 The Regulations for classification and assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations* to which reference should be made on the survey request form.

1.3.8 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 1 or 2, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.4 Information required

1.4.1 For the information required, *see Pt 3, Ch 1, 5 Information required*. In addition, the following are to be supplied:

(a) The draught desired in conjunction with the contemplated loading sequence, *see also Pt 4, Ch 1, 2.1 Materials and grades of steel 2.1.1*.

(b) Cargo loading on inner bottom and if applicable, also on hatchways and deck, *see Pt 4, Ch 1, 1.3 Class notation* and *Pt 3, Ch 3, 4 Design loading*.
(c) Container stack weights, *see Pt 4, Ch 1, 9.1 Double bottom structure, general 9.1.2*.
(d) The maximum pressure head in service on tanks. Where tanks are interconnected with side tanks, this is to be clearly specified.
(e) Details of tanks which will be solely used for water ballast in the light condition and which will be empty in the loaded condition.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T and C_b are as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

k_L is given in *Pt 3, Ch 2, 1.3 Steel 1.3.2*

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

l = overall length of stiffening member, in metres, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

s = spacing of secondary stiffeners, i.e. frames, beams or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3 Structural idealisation*.2

S = spacing or mean spacing, of primary members, i.e. girders, transverses, webs, etc. in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

■ *Section 2* Materials and protection

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of *Pt 3, Ch 2, 1 Materials of construction*

2.1.2 Grades of steel used in the construction of continuous coamings are to comply with *Table 1.2.1 Grades of steel of continuous coamings*.

Table 1.2.1 Grades of steel of continuous coamings

Thickness, t, in mm	Mild Steel	H.T. steel
$t \leq 20$	A	AH
$t > 20$	D	DH

2.2 Protection of steelwork

2.2.1 For the protection of steelwork, the requirements of *Pt 3, Ch 2, 2 Corrosion protection* and *Pt 3, Ch 2, 3 Deck covering* are to be complied with.

■ Section 3
Longitudinal strength

3.1 General

3.1.1 The longitudinal strength of a dry cargo ship is to comply with the requirements of *Pt 3, Ch 4 Longitudinal Strength* for the longitudinal strength Category contemplated.

■ Section 4
Deck plating and continuous longitudinal hatch side coamings

4.1 General

4.1.1 The requirements of this Section cover the topside structure which includes the following structural parts of the ship:

- deck plating and continuous longitudinal hatch coamings.

4.1.2 For ships over 65 m in length, the thickness of the deck and coaming plating may require to be increased to obtain the midship section modulus required in *Pt 3, Ch 4 Longitudinal Strength*.

4.2 Deck Plating

4.2.1 The thickness of the deck plating is to comply with *Table 1.4.1 Topside structure (general)*, and is generally to be maintained one frame space fore and aft of the hatch opening. The plating thickness may however be reduced beyond 0,5*L* amidships in accordance with the requirements for taper given in *Pt 3, Ch 3, 2.5 Principles for taper* As an alternative, direct calculations may also be used to prove that the allowable stresses given in Section 13 will not be exceeded. The thickness at the end of the hatch opening should however be not less than 80 per cent of the thickness amidships nor less than the minimum thickness required by *Table 1.4.1 Topside structure (general)*.

4.2.2 Openings in the deck should be kept to a minimum and are to be arranged clear of the hatch corners; compensation for these openings will generally be required.

Table 1.4.1 Topside structure (general)

Item and parameter	Requirements for all ships
(1) Deck thickness	The greater of: $t = (5,6 + 0,039L)\sqrt{s}$ mm $t = 10s$ mm
(2) Hatch coaming minimum thickness	The greater of: $t = 0,042(L_1 + 200)d_c$ mm $t = (6 + 0,06L)\sqrt{d_c}$ mm
(3) Upper hatch coaming stiffener inertia	$I_s = S^2 A_{st}$ cm^4
Symbols	

	=	*L*, *D* and *s* are as defined in *Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1*
d_c	=	vertical distance, in metres, between deck and horizontal stiffener on coaming or between horizontal stiffeners
A_{st}	=	area of stiffener including attached plating, in cm^2
S	=	distance between coaming stiffeners, in metres
L_1	=	*L* but to be taken not less than 40 m
I_s	=	upper hatch coaming stiffener inertia

Note The scantlings of the topside structural parts may require to be increased to satisfy the hull girder bending stresses and buckling criteria in*Pt 3, Ch 4 Longitudinal Strength*.

4.3 Continuous longitudinal hatch coamings

4.3.1 The thickness of the coaming is to comply with the requirements of *Table 1.4.1 Topside structure (general)* and is to be maintained over the length of the hatch opening. The plating thickness may, however, be reduced beyond 0,5*L* amidships in accordance with the requirements for taper given in *Pt 3, Ch 3, 2.5 Principles for taper*. Where coaming terminates at the end(s) of the hold, the combined taper area of the topside comprising coaming, deck and sheerstrake is to be used. As an alternative, direct calculations may also be used to prove that the allowable stresses given in Section 13 will not be exceeded. The thickness at the end of the hatch opening should, however, be not less than 80 per cent of the thickness amidships nor less than the minimum thickness required by *Table 1.4.1 Topside structure (general)*

4.3.2 The height of the hatch coaming is, in general, to be not more than 1,60 m above the deck and the hatch coaming is to extend at least 250 mm below the deck plating to provide for an efficient connection of the frame brackets and is to be substantially stiffened at the lower edge.

4.3.3 Coamings are to be stiffened at their upper edge by a substantial horizontal stiffener having scantlings complying with *Table 1.4.1 Topside structure (general)* The distance between the upper edge of the coaming and this stiffener is, generally, not to exceed 10 times the coaming thickness in way. If the height of the coaming is more than 1,0 m above deck, it is recommended to fit an additional horizontal stiffener halfway between the upper horizontal stiffener and the deck. Proposals to omit the longitudinal stiffener(s) are to be supported by additional buckling calculations.

4.3.4 Cut-outs in the upper edge of the coaming to accommodate hatchcovers are to be carefully designed and cut, with small rounded corners and be ground smooth after cutting. Hull girder bending stresses are to be calculated at the level of the lower edge of the cut-out.

4.3.5 Hatch coaming stays are to be fitted not more than 3 m apart. On ships regularly discharged by grabs, the distance between the stays is not to exceed 2 m.

■ *Section 5*
Hull envelope plating

5.1 General

5.1.1 This Section covers the requirements for the shell envelope plating, *viz*., keel, bottom, bilge and side shell plating. For deck plating, *see Pt 4, Ch 1, 4 Deck plating and continuous longitudinal hatch side coamings* . The thickness of shell envelope plating amidships is to be not less than required in *Table 1.5.1 Shell envelope plating*, but for ships over 65 m in length, the thickness of the bottom plating may require to be increased to obtain the midship section modulus required in *Pt 3, Ch 4 Longitudinal Strength*.

5.1.2 For requirements in respect of structural details, *see Pt 3, Ch 10 Welding and Structural Details*.

5.2 Keel

5.2.1 The thickness and breadth of the keel plate is to comply with the requirements of *Table 1.5.1 Shell envelope plating*and is to be maintained over the full length of the ship

5.2.2 The scantlings of a bar keel, if fitted, are to comply with the requirements of *Table 1.5.1 Shell envelope plating*.

5.3 Shell plating

5.3.1 The thickness of bottom shell and side shell plating is to be maintained over 0,5*L* amidships. Thicknesses are to comply with *Table 1.5.1 Shell envelope plating* and may be tapered to the end thickness in the fore end and aft end of the ship, *see Pt 3, Ch 5 Fore End and Aft End Structure*, according to the requirements for taper given in*Pt 3, Ch 3, 2.5 Principles for taper*. Where the bottom is transversely framed, the bottom is, in general, to be reinforced with additional longitudinal stiffeners.

Table 1.5.1 Shell envelope plating

	Item and parameter	Requirement
(1)	Plate keel breadth	$0{,}1B$ but not less than 0,75 m
	Thickness	As bottom plating t_b When there is a rise of floor, the thickness is to be increased by 1 mm
(2)	Bar keel thickness	$t = 0{,}37L + 10$ mm
	Height	$d_k = 0{,}7L + 75$ mm
(3)	Bottom plating thickness	The greater of:
		$t_b = (5{,}6 + 0{,}054L)\sqrt{s}$
(4)	Bilge plating thickness	$t = t_b + 2$ mm
(5)	Bilge chine bars	
	(a) Round bars diameter	$3t_b$ mm, but not less than 30 mm
	(b) Square bars side	$3t_b$ mm, but not less than 30 mm
	(c) Angle bars flange thickness	$t = 2t_b$ mm
(6)	Side shell plating	The greater of:
	Thickness	$t = (5{,}6 + 0{,}054L)\sqrt{ks}$
		$t = 10s$
(7)	Minimum width sheerstrake	$W_{sh} = 0{,}08D$ m
		but not less than 0,20 m
(8)	Sheerstrake thickness	t = side shell thickness + 5 mm
(9)	Doublers clear of sheerstrake (when fitted)	
	Width	W_d = between 0,10 and 0,45 m
	Thickness	The greater of
		$t = 30W_d$
		t = required thickness for the side shell plating
Symbols		
L, *B*, *D*, *s*, *k* and *t* are as defined in *Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1*		
d_k = height of bar keel		

t_b = thickness of bottom plating, in mm
Note The thickness of the bottom plating is also to satisfy the buckling requirements and hull girder stress criteria in *Pt 3, Ch 4 Longitudinal Strength*.

5.4 Bilge plating

5.4.1 The thickness of the bilge plating is to be maintained from amidships to well beyond the forward and aft shoulder of the bilge, but at least over the midship region. For definition of shoulders, *see Pt 3, Ch 5, 2.4 Shell plating 2.4.2*.

5.4.2 The bilge radius is to be at least 10 times the thickness of the bilge plating and the bilge strake is to extend at least 100 mm on either side of the radius of the bilge plate.

5.4.3 Square bilges, constructed by solid round, square or externally fitted angle bars, *see Figure 1.5.1 Square bilge arrangements*, are to comply with *Table 1.5.1 Shell envelope plating*. The bottom plating and the side shell plating, adjacent to the round, square or angle bars need not be increased in thickness above that of the bottom plating or side shell plating in way.

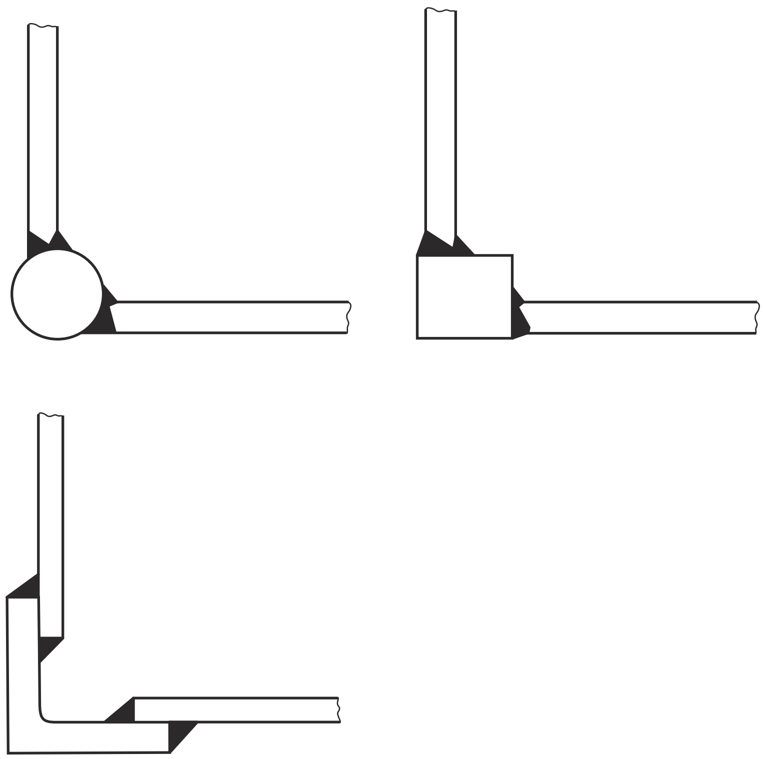


Figure 1.5.1 Square bilge arrangements

5.5 Sheerstake

5.5.1 The width and thickness of the sheerstrake is to comply with *Table 1.5.1 Shell envelope plating*, and is to be maintained over the length of the hatch opening, including one frame space forward and aft of the hatch opening, but at least over 0,5*L* amidships.

5.6 Shell openings

5.6.1 Openings in the shell plating are to have well-rounded corners; compensation is generally only required for openings having a width greater than 250 mm. Openings in way of or near to the bilge radius fitted in the midship region are to be circular or elliptical.

Section 6
Single bottom structure

6.1 General

6.1.1 Requirements are given in this Section for transversely framed single bottoms. The scantlings of girders and floors are to be not less than required in *Table 1.6.1 Transversely framed singled bottom*.

Table 1.6.1 Transversely framed singled bottom

Item	Parameter	Requirements
(1) Centreline girder	Web and face plate thickness	$t = (0{,}008d_{\text{w}} + 3)\sqrt{k}$ mm, *see* Note
	Width of face plate	$b_{\text{f}} = 140s$ mm
(2) Side keelson bars	Cross-sectional area	$A_{\text{k}} = 8 + 0{,}6B$ cm^2
(3) Floors	Web depth at centreline	$d_{\text{w}} = 40B$ mm
	Web thickness	$t_{\text{w}} = (0{,}008d_{\text{w}} + 3)\sqrt{k}$ mm, *see Note*
	Face plate thickness	$t \le t_{\text{w}}$
	Ratio of unsupported face plate width and face plate thickness	max 15
	Minimum required modulus	$Z = 6kT\,s\,B^2$ cm^3
	Inertia	$I = \dfrac{2{,}2}{k} \times Zl$ cm^4
Symbols		
Z, B, T, s, k and t are as defined in *Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1* b_{f} = width of face plate of floor or girder, in mml d_{w} = web depth of floor or girder, in mm t_{w} = thickness of floor web plate, in mm A_{K} = cross-sectional area of keelson bar, in cm^2		
Note In ships regularly discharged by grabs the thickness of floors and girders is to be not less than 8 mm.		

6.1.2 It is recommended that the bottom of ships intended regularly to rest aground be additionally strengthened in order to withstand the increased loads to which they may be subjected. Scallops or openings (unless reinforced) are not permitted.

6.1.3 In general, single bottom structures are only to be used in general dry cargo ships designed for a stowage rate greater than 1,39 m^3/tonne, corresponding to a specific weight of cargo less than 0,72 tonne/m^3. For stowage rates less than 1,39 m^3/tonne, the scantlings will be specially considered.

6.2 Girders

6.2.1 A centreline girder is to be fitted and is to have the same depth as the floors at centreline. If the breadth of the ship exceeds 7 m, side keelson bars are to be fitted on top of floors spaced not more than 3 m apart. The keelson bars are to be channel bars or other bars with sufficient rigidity.

6.3 Floors

6.3.1 Plate floors are to be fitted at every frame. The top of floors may be level from side to side, but in ships having considerable rise of floor, the depth of the floor plates is to be suitably increased. The floors may be cut at the centreline, with the centre girder web plate continuous, provided the transverse strength of the floors is maintained. The upper edge of the floors is to be suitably stiffened. Floors which are subjected to concentrated loads will be specially considered.

6.3.2 Floors are to be provided with drain holes, sufficient in number and size, to allow water to flow to the pump suctions.

6.4 Ceiling

6.4.1 Close ceiling is to be laid on floors and/or girders of single bottom arrangements, on inner bottom plating of double bottoms and over bilges if fitted, and is to be readily removable. The spaces between the frames at the top of bilge ceiling are to be closed by steel plates or other suitable means such as wooden chocks, cement, etc. Inner bottom manhole covers or fittings, if projecting above the inner bottom plating, are to be properly protected.

6.4.2 The thickness of ceiling is given in *Table 1.6.2 Ceilings*.

Table 1.6.2 Ceilings

Single bottom ceilings	Thickness	
	Soft wood	Hard wood
Frame spacing maximum 0,5 m, *see* Note	50 mm	38 mm
Ships regularly discharged by grabs	—	50 mm
Note If the frame spacing is in excess of 0,5 m the thickness of the ceiling is to be: $\dfrac{\text{Actual frame spacing in m} \times \text{table thickness}}{0,5}$		

6.4.3 Where the frames are inclined forward and aft in the holds, it is recommended that cargo battens be arranged in these areas.

■ *Section 7* Double bottom structure

7.1 General

7.1.1 Requirements are given in this Section for a double bottom construction with a transverse or a longitudinal framing system. The scantlings of girders, floors, inner bottom plating and longitudinals are to be not less than required in *Table 1.7.1 Double bottom structure*. *See also Pt 4, Ch 1, 8 Additional requirements for double bottom structures in bulk carriers* and *Pt 4, Ch 1, 9 Additional requirements for container ships* for additional requirements for bottom structures in Bulk Carriers and Container ships.

Table 1.7.1 Double bottom structure

Item		Parameter	Requirement
(1)	Double bottom at centreline	Minimum depth	$d_f = 35B$ mm
(2)	Centreline girder and side girder	Thickness	The greater of: $t = (0{,}008d_f + 3{,}0)\sqrt{k}$ mm $t = 8{,}0$ mm

(3)	Floors in a transverse framing system	Thickness	The greater of:
			$t = (0{,}0085 d_f + 2{,}0)\sqrt{k}$ mm
			t = 7,0 mm
		Modulus	$Z = CkTsl_b^{\ 2}$ cm^3
(4)	Floors in a longitudinal framing system	Thickness	The greater of:
			$t = (0{,}009\ d_f + 2{,}0)\sqrt{k}$ mm
			t = 8,0 mm
		Modulus	$Z = CKTsl_b^{\ 2}$
(5)	Watertight floors	Thickness	The greater of:
			$t = (0{,}0085\ d_f + 3{,}0)\sqrt{k}$mm
			t = 8,0 mm
(6)	Inner bottom plating	Thickness	The greater of:
			$t = 12\ s$ mm
			t = 6,0 mm
(7)	Inner bottom longitudinals	Modulus	$Z = 4{,}85kH_c sl_e^2$ cm^3
(8)	Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)\ D_1ksl_e^{\ 2}$ cm^3

Symbols

L, B, D, T, S, s, t and Z are as defined in *Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1*

l_b = the width of the double bottom, in metres, and is normally the breadth of the ship. If longitudinal bulkheads or equivalent supports are provided, an equivalent breadth may be used, but this is to be taken as not less than 0,8B

l_e = effective length of stiffening members, in metres, as defined in *Pt 3, Ch 3, 3.3 Determination of span point*, but is to be taken not less than 1,5 m

t_i = thickness of inner bottom plating or bottom plating, whichever is the lesser, in mm

A_s = minimum web sectional area at ends of floors (at toes of frames), in cm^2

D_1 = D, but need not be taken greater than T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1

H_c = height from inner bottom to underside of deck or to the top of hatch coaming, in metres, as defined in *Pt 3, Ch 3, 4.2 Symbols 4.2.1*

L_1 = L but is to be taken not less than 65 m, nor greater than 110 m

C = 6 for general dry cargo ships and container ships

C = 7 for bulk carriers

7.1.2 The depth of the double bottom is to comply with the requirements of *Table 1.7.1 Double bottom structure*, but it is recommended that the double bottom space be accessible for inspection and surveys, *see Pt 1, Ch 3, 4.2 Examination and testing 4.2.6*

7.1.3 Provision is to be made for free passage of air and water from all parts of the double bottom compartments to the air pipes and suctions, account being taken of the pumping rates required. Where access openings are cut in the floors and girders, the size of openings should not, in general, exceed 50 per cent of the double bottom depth. Openings are to be avoided in way of ends of floors and girders, and in way of concentrated loads.

7.2 Girders

7.2.1 A centreline girder is generally required in ships with a breadth, *B*, of more than 6 m. A side girder is to be fitted on each side of the centreline in ships with a breadth, *B*, of more than 12 m and transversely framed bottom construction. Proposals to omit the centreline girder and/or side girders will be specially considered, but adequate support must be provided on the centreline for docking purposes.

7.3 Floors

7.3.1 In transversely framed double bottoms, floors are to be fitted at every frame.

7.3.2 In longitudinally framed double bottoms, floors are to be fitted at a spacing not exceeding 2,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. In between the floors, brackets are to be fitted in the double bottom in line with the transverse side frames, connected to tank top and shell plating and extending to the nearest bottom and inner bottom longitudinal. Midway between floors, brackets are to be fitted on either side of the centreline, extending to the nearest bottom and inner bottom longitudinals. The free edges of the brackets are to be suitably stiffened.

7.3.3 Plate floors are also to be arranged under bulkheads, and in line with web frames fitted in the side structure. Floors subjected to concentrated loads will be specially considered.

7.4 Inner bottom plating

7.4.1 The thickness of the inner bottom plating is to comply with the requirements of *Table 1.7.1 Double bottom structure*. Where no ceiling is laid on the inner bottom plating, the thickness of the plating is to be increased by 2 mm. The inner bottom plating may be attached by slot fillet welds to the face bars or flanges of the floors.

7.5 Longitudinals

7.5.1 The scantlings of bottom longitudinals and inner bottom longitudinals are to comply with the requirements of *Table 1.7.1 Double bottom structure* and are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*.

■ *Section 8*
Additional requirements for double bottom structures in bulk carriers

8.1 General

8.1.1 The requirements of *Pt 4, Ch 1, 7 Double bottom structure* are to be applied together with the requirements of *Table 1.8.1 Requirements for double bottom structures in bulk carriers* in this Section.

Table 1.8.1 Requirements for double bottom structures in bulk carriers

Item	Parameter	Requirements
(1) Inner bottom plating	Thickness	The greater of: $t = 4s\sqrt{kp_0}$ mm t = 8,0 mm This thickness is to be increased by 4 mm when no ceiling is fitted
(2) Girders and floors	Thickness	Not less than 8 mm

(3)	Inner bottom longitudinals	Section modulus	(1) Within 0,25B on either side of centreline: $Zl = 7{,}25 P_o k s l_e^{\ 2}$ cm^3 (2) Outside 0,25B from centreline: The greater of: (a) $Z = 0{,}5 Zl$ cm^3 (b) $Z = 4{,}85 H_c k s l_e^{\ 2}$ cm^3
Symbols			
L, B, D, T, C_b, H_c, le, S, s, t, k and Z are as defined in *Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1* and *Table 1.7.1 Double bottom structure* $P_0 = 1,8\sqrt{\left[\frac{B}{r}\left(T\,C_b - 0,16D\right)\right]}\ t/m^2$ r = ratio cargo compartment length, in metres/L			
Note The application of higher tensile steel inner bottoms will be specially considered.			

■ *Section 9*
Additional requirements for container ships

9.1 Double bottom structure, general

9.1.1 The minimum scantlings of structural members of single and double bottoms are to comply with the requirements of *Pt 4, Ch 1, 6 Single bottom structure* and *Pt 4, Ch 1, 7 Double bottom structure*, as applicable, but are to be confirmed by direct calculations in accordance with this Section.

9.1.2 A minimum container mass of 15 tonnes should be taken into account for either 20 ft or 40 ft containers. This figure is to be multiplied with the number of tiers of containers intended to be carried. Where it is intended to carry more than 4 tiers, the upper tier may be assumed empty. As an example, in case of a ship designed to carry 4 tiers of containers, a minimum stack load of 60 tonnes will need to be used. The bottom structure may be designed for higher stack loads as desired. The values of allowable container stack loadings are to be supplied to the ship.

9.1.3 The requirements given in this Section are based on the assumption that continuous girders are fitted under the container corners.

9.1.4 Local stiffening will be required under container corners, and the locations of the corners are to be clearly marked in the inner bottom plating or hold ceiling when no permanent container corner seatings are provided on the inner bottom.

9.1.5 Additional requirements regarding the double bottom structure are given in *Pt 4, Ch 1, 9.3 Girders in the double bottom*, *Pt 4, Ch 1, 9.4 Double bottom floors and transverses* and *Pt 4, Ch 1, 9.5 Assessment of bottom structure by direct calculation*.

9.2 Torsional strength

9.2.1 The mass of the containers is to be evenly distributed over the width of the ship, thus preventing high torsional moments being imposed. If high torsional moments are foreseen or are to be incorporated in the design the values of these torsional moments are to be indicated on the structural plans of the cargo part and on the midship section plan. In such cases, the torsional strength of the ship will be specially considered.

9.3 Girders in the double bottom

9.3.1 Where no centreline girder is fitted, adequate support on the centreline must generally be provided for docking purposes.

9.3.2 Partial girders may be required close to the bottom girders to spread the container loads locally over the bottom structure. The partial girders in way of the container corners as indicated in *Figure 1.9.1 Schematic bottom structure* and *Figure 1.9.2 Schematic bottom structure (longitudinal framing)* are to have the same thickness as the continuous girders.

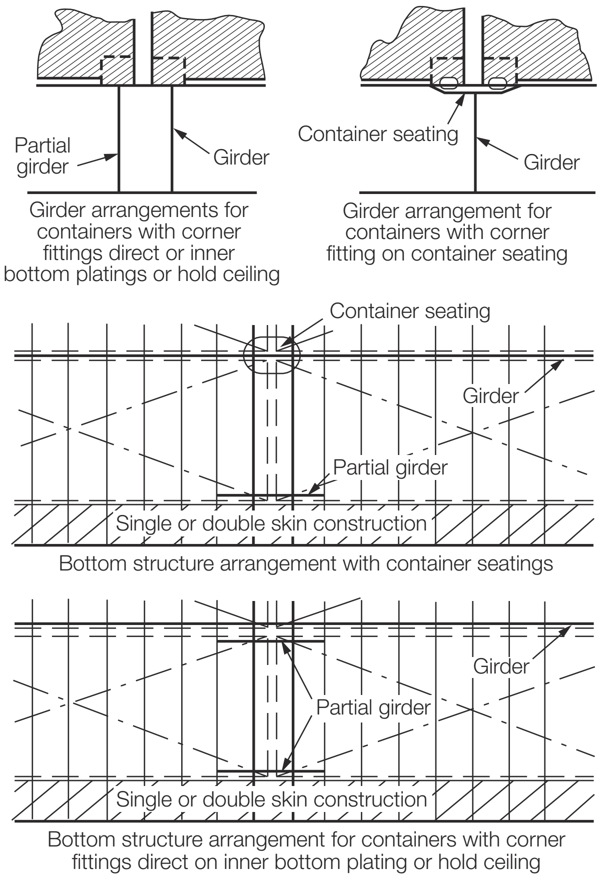


Figure 1.9.1 Schematic bottom structure

9.3.3 In single bottoms, in way of the container corner fittings, gusset plates are to be fitted connecting the floors or transverses to the longitudinal girders. The gusset plates are to extend over at least three floors or transverses and are to be tapered off in the fore and aft direction. *See Figure 1.9.3 Gusset plate arrangements*.

9.4 Double bottom floors and transverses

9.4.1 In a longitudinal framing system, floors or transverses are to be fitted at a spacing not exceeding 2,0 m. Special attention is to be paid to the distribution of shear loads and resulting shear stresses in floors and longitudinal girders directly loaded by containers, and this aspect is to be verified by direct calculations. Where necessary, additional panel stiffeners or web plating of increased thickness may need to be fitted in order to prevent local plate buckling.

9.4.2 Special attention should be paid to the shear strength of floors under container fittings in way of the connection with the side shell structure. For this purpose, the web thickness may require to be locally increased.

9.4.3 Where a double hull has been provided, the inner bottom plating in way of the floors is to be suitably scarfed into the double hull structure by means of horizontal gusset plates or equivalent.

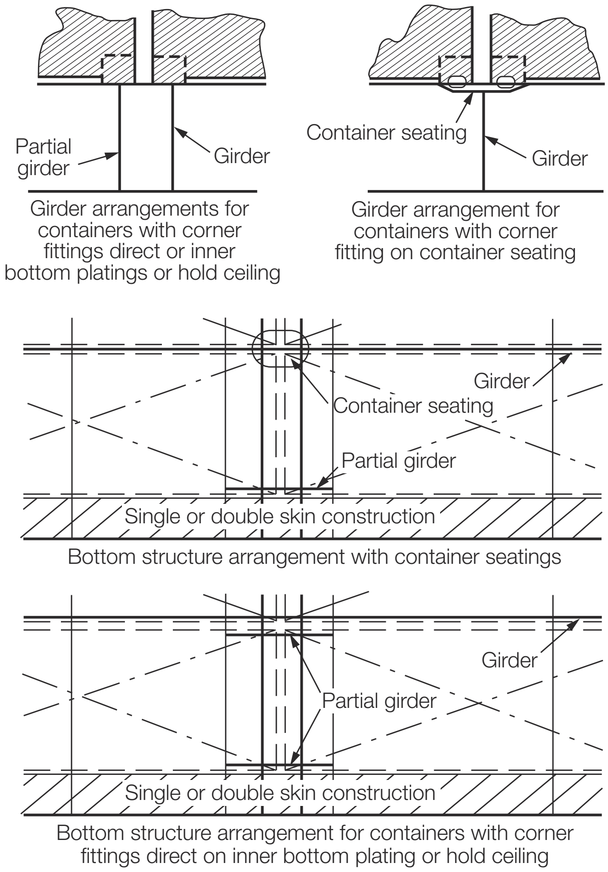
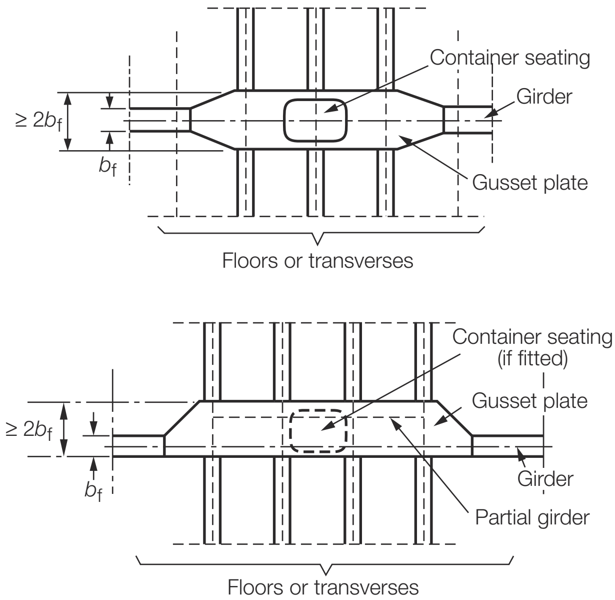


Figure 1.9.2 Schematic bottom structure (longitudinal framing)



Thickness of gusset plates is to be not less than thickness of faceplates of floors, transverses or girders, whichever is the greater

Figure 1.9.3 Gusset plate arrangements

9.5 Assessment of bottom structure by direct calculation

9.5.1 The scantlings of the bottom structure are to be determined by direct calculations in accordance with this sub- Section, together with procedures and criteria as outlined in *Pt 4, Ch 1, 13 Direct calculation procedures*.

9.5.2 The calculation is to be carried out as a finite element analysis of the bottom structure, generally covering the bottom structure extending over one container length. Smaller extents, i.e. half container lengths may be used depending on the degree of uniformity of the bottom structure.

9.5.3 The analysis of the bottom structure is to be carried out for the bottom loaded by container point loads (for 20 ft and 40 ft containers as applicable) whereby the draught of the ship is to be taken not greater than 0,4T for ships with loading sequence notation LS'O' and 0,6T for ships with notations LS'T' or LS'D'.

9.6 Stability

9.6.1 Attention is drawn to the intact stability requirements as contained in the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN).

■ *Section 10*
Single side shell and deck supporting structure

10.1 General

10.1.1 This Section covers the arrangements and requirements for one of the following transverse framing systems:

(a) Support of the side shell and deck by framing of equal profile depth only.
(b) Support of the side shell and deck by a combination of frames and web frames or bulkheads.

10.1.2 The scantlings of the side shell structural parts, *viz*. frames, web frames and the brackets under deck from frame to coaming are to comply with *Table 1.10.1 Single skin construction*.

10.1.3 Where a longitudinal framing system is adopted, the scantlings and arrangements will be specially considered.

10.2 Frames

10.2.1 In ships with a single bottom, the lower end of the frames is to overlap the floors. In ships with a double bottom, the lower end of the frame is to be efficiently connected to the double bottom structure.

10.3 Web frames

10.3.1 If web frames are fitted, they are to be spaced not more than 5 m apart. The thickness, stiffening arrangement and end connections of web frames are to be in accordance with the requirements of *Pt 3, Ch 10, 4 Construction details for primary members*.

10.4 Brackets under deck

10.4.1 At the head of frames and web frames, brackets are to be fitted supporting deck and hatch coaming. The arrangements of the brackets is shown in *Figure 1.10.1 Frame arrangement*. The scantlings of the brackets at the frames and web frames are to have equal dimensions, it being assumed that the load from coaming and deck is evenly distributed over each bracket. Proposals for other structural arrangements resulting in a different distribution of loads will be specially considered. Where a travelling crane for the lifting of hatch covers or cargo is used, the load from the crane is also to be taken into account when calculating the bracket scantlings.

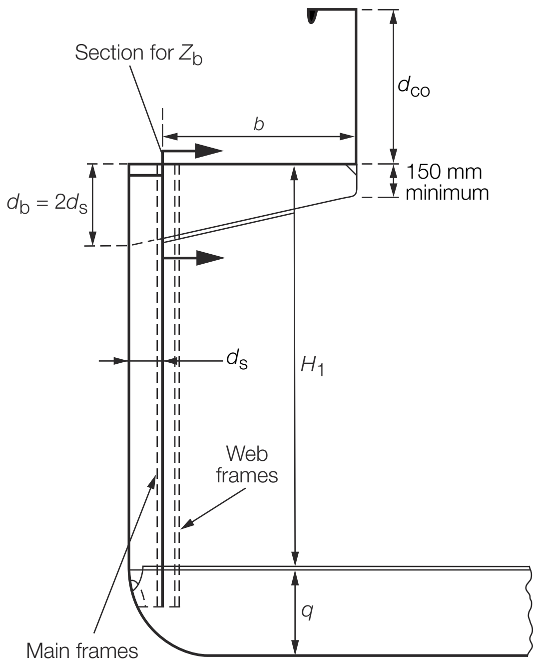


Figure 1.10.1 Frame arrangement

Table 1.10.1 Single skin construction

Item	Parameter	Requirement
(1) Frames	Modulus	$Z_f = 1,5 k_1 s T_1^3 \left(10 + 3\left(\frac{T_1}{H_1}\right)^2 - \frac{10T_1}{H_1} \right) + Z_b$ cm^3

(2) Web frames	Modulus	$Z = 5,6kS\frac{T_1^4}{H_1^2}(5H_1 - 2T_1)$ $+ Z_b \text{cm}^3$
(3) Brackets under deck	Depth	d^b = as shown in *Figure 1.10.1 Frame arrangement*
	Thickness	$t = 4 + 0,3\sqrt{Z_f}$ mm
	Flange width	b_f = 70 mm minimum
	Minimum required modulus	$Z_b = 29k \times k_2 \times b \times s\,(b \times h_1 + b_1 \times h_h)$ cm^3
Symbols		

D, T, S, s, t, k and z are as defined in *Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1*

b = width of bracket, in metres, as shown in *Figure 1.10.1 Frame arrangement*

b_f = width of bracket flange, in mm

b_1 = width of hatchway, in metres

h_h = head, in metres, on the hatch covers (if fitted) as defined in *Pt 3, Ch 3, 4 Design loading*

h_1 = head on deck, in metres, as defined in *Pt 3, Ch 3, 4 Design loading*

k_1 = 1 + (u – 15) x 0,078, but this factor is to be not less than 1, nor greater than 3,33, where

u = distance between transverse bulkheads, web frames or other efficient transverse supports, in metres

k_2 = $L_{co}/12d_{co}$ – 1, but this factor is to be taken not less than 0, nor greater than 1, where

L_{co} = length of hatch coaming between transverse bulkheads, or other efficient vertical supports, in metres

d_{co} = depth of hatch coaming, in metres, as shown in *Figure 1.10.1 Frame arrangement*

q = height of single or double bottom, in metres, as shown in *Figure 1.10.1 Frame arrangement*

H_1 = vertical framing depth, in metres, as shown in *Figure 1.10.1 Frame arrangement*

T_1 = $D – q$ but need not be taken greater than T + 0,4 – q for Zone 3, T + 0,7 – q for Zone 2, T + 1,0 – q for Zone 1, in metres

Z_b = modulus, in cm^3, of brackets under deck at the intersection with the frame as indicated in *Figure 1.10.1 Frame arrangement*

Z_f = modulus of the frame, in cm^3

Note 1. Where frames do not support cantilever brackets under deck, a minimum value of 15 cm^3 for Z_b is to be applied.

Note 2. Z_b is to be obtained from (3) taking k_2= 1 and s as the spacing between web frames

Note 3. If the factor k_2 is 0, the frame bracket may also be replaced by a deck beam with a section modulus not less than half the section modulus of a frame and suitably connected to the frame.

■ *Section 11*
Double skin structure

11.1 General

11.1.1 This Section covers the arrangements and requirements for transversely and longitudinally framed side shell structures of double skin ships.

11.1.2 The scantlings of the double skin structure, except side shell plating, are to comply with *Table 1.11.1 Double skin structure (General requirements)*. For side shell plating, *see Pt 4, Ch 1, 5 Hull envelope plating*.

11.1.3 The side shell may be transversely or longitudinally framed. The longitudinal bulkheads are in general to have the same framing system as the shell.

11.2 Transverse framing

11.2.1 The lower ends of side frames and stiffeners of longitudinal bulkheads may overlap the floors or otherwise be connected to the floors or tank top by means of brackets. At their upper ends, side frames and bulkhead stiffeners are to be interconnected by means of brackets, *see Figure 1.11.1 Frame arrangement (transverse framing)*.

11.2.2 In addition to the frames, plate webs are to be fitted spaced not more than 8 m apart, *see also Figure 1.11.2 Arrangement of plate webs*. Manhole openings are to be provided in the plate webs to allow for inspection. Horizontal stiffeners are to be fitted to the plate webs, spaced not more than twice the frame spacing apart. Plate webs with large access holes are to be additionally stiffened and their scantlings are to be verified by direct calculations. The scantlings of truss-type web frames, replacing plate webs and composed of rolled or built sections, are to be determined by direct calculation.

11.2.3 Alternatively, plate webs in accordance with *Pt 4, Ch 1, 11.2 Transverse framing 11.2.2* may be fitted at every frame.

Table 1.11.1 Double skin structure (General requirements)

Item	Parameter	Requirement
(1) Shell frames	Modulus	$Z_f = 1,5kk_1sT_1^3\left(10+3\left(\frac{T_1}{H_1}\right)^2 - \frac{10T_1}{H_1}\right) + 2H_1T_s\sqrt{B}$ cm^3
(2) Vertical stiffeners on longitudinal bulkhead	Modulus	$Z = Z_f$
(3) Brackets under deck	Depth Thickness Flange width	d_b as shown in *Figure 1.11.1 Frame arrangement (transverse framing)* $t = 4 + 0,3\sqrt{Z_f}$ mm $b_f \geq 70$ mm
Longitudinal framing systems		
(4) Shell longitudinals	Modulus	$Z = \left(4,6 + 0,0342L_1\right)kh_s s l_e^2$ cm^3, *see* Note 1
(5) Horizontal stiffeners on longitudinal bulkhead	Modulus	$Z_I = 8kh_4 s l_e^2$ cm^3, *see* Note 1
(6) Web frames at shell, *see Figure 1.11.3 Arrangement for web frames*	Modulus	$Z_w = 1,2kT_1^3 s\left(7 - \frac{4T_1}{H_1}\right)$ cm^3
(7) Web frames on longitudinal bulkhead, *Figure 1.11.3 Arrangement for web frames*	Modulus	$Z = Z_w$
(8) Bracket under deck	Depth Thickness Flange width	$d_b$as shown in *Figure 1.11.1 Frame arrangement (transverse framing)* $t = 4 + 0,3\sqrt{Z_f}$ mm $b_f \geq 70$m
Transverse and longitudinal framing systems		
(9) Plating of longitudinal bulkhead, *see* Notes 2 and 3	Thickness	$t = (5,6 + 0,054L)\sqrt{s}$

(10) Plate webs, *see Figure 1.11.2 Arrangement of plate webs*	Thickness	The greater of t = 7mm $t = 10s_d$ $t(c) = 2 + 2,8D$
(11) Horizontal stiffeners on webs	Width Thickness	$W = 125b$mm t = thickness plate webs
Symbols		
L, B, D, T, S, s, t, k, Z and $l$are as defined in *Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1*		
b = breadth of side shell structure, in metres, as indicated in *Figure 1.11.2 Arrangement of plate webs* h_s = $h_{de} + h_t$ but not less than 2,0 m h_{de} = distance of longitudinal to the deck at side, in metres h_t = 0 for void spaces = 0,50 for deep tanks but not less than the distance to the top of the overflow q = height of single or double bottom, in metres, as shown in *Figure 1.11.1 Frame arrangement (transverse framing)* s_1 = spacing between horizontal stiffeners, in metres s_d = stiffener spacing or width of double skin, whichever is the smaller	t_s = thickness of side shell, in mm H_1 = vertical framing depth, in metres, as shown in *Figure 1.11.1 Frame arrangement (transverse framing)* and *Figure 1.11.2 Arrangement of plate webs* L_1 = L, but is to be taken as not less than 50 m nor more than 100 m S_b = spacing of plate webs, in metres h_4 = ho + 0,5 b1 = the greater of the distance, in metres, from the middle of the effective length to the top of the cargo or = 1,5 m = whichever is the greatest h_O = the vertical distance, in metres, from the mid-point of span of the stiffener to the highest point of the tank including hatchway b_1 = the horizontal distance, in metres, from the centre line to the hatchway in way of the cargo hatch T_1 = $D - q$, but need be taken not greater than T + 0,4 – q for Zone 3, T + 0,7 – q m for Zone 2, T + 1,0 – q m for Zone 1, in metres Z_f = modulus of frame, in cm^3 Z_l = modulus of side shell longitudinal, in cm^3 Z_w = modulus of web frame, in cm^3	
Note 1. The web thickness of longitudinals is not to be less than 7 mm. **Note** 2. For bulk carriers it is recommended to add 3 mm to the thickness of the lower edge of the bulkhead over a height of about 250 mm above the inner bottom. **Note** 3. The thickness of the upper strake of the longitudinal bulkhead may require to be increased to satisfy the hull girder bending stress criteria in *Pt 3, Ch 4 Longitudinal Strength*		

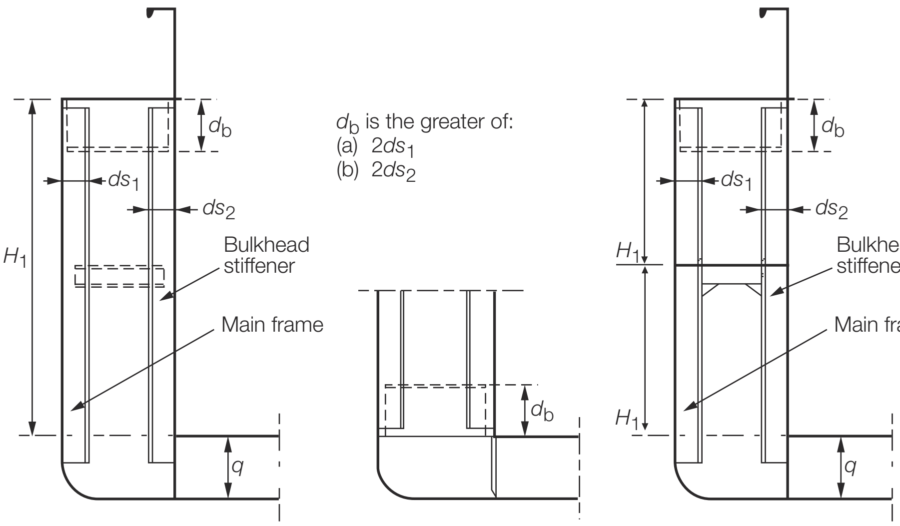


Figure 1.11.1 Frame arrangement (transverse framing)

11.3 Longitudinal framing

11.3.1 Longitudinals on shell and longitudinal bulkheads are to be supported by web frames, spaced not more than 2,5 m apart, and efficiently connected thereto.

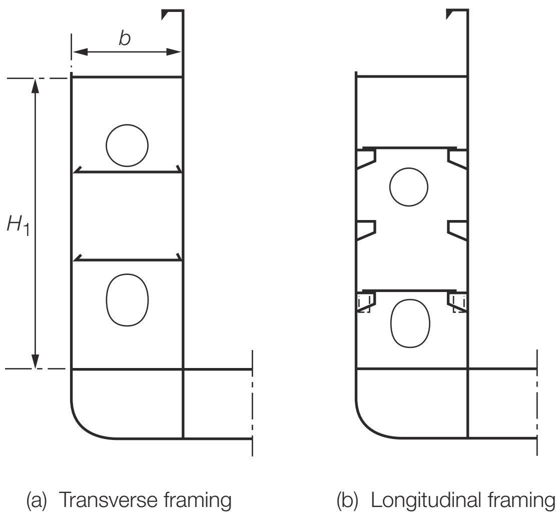


Figure 1.11.2 Arrangement of plate webs

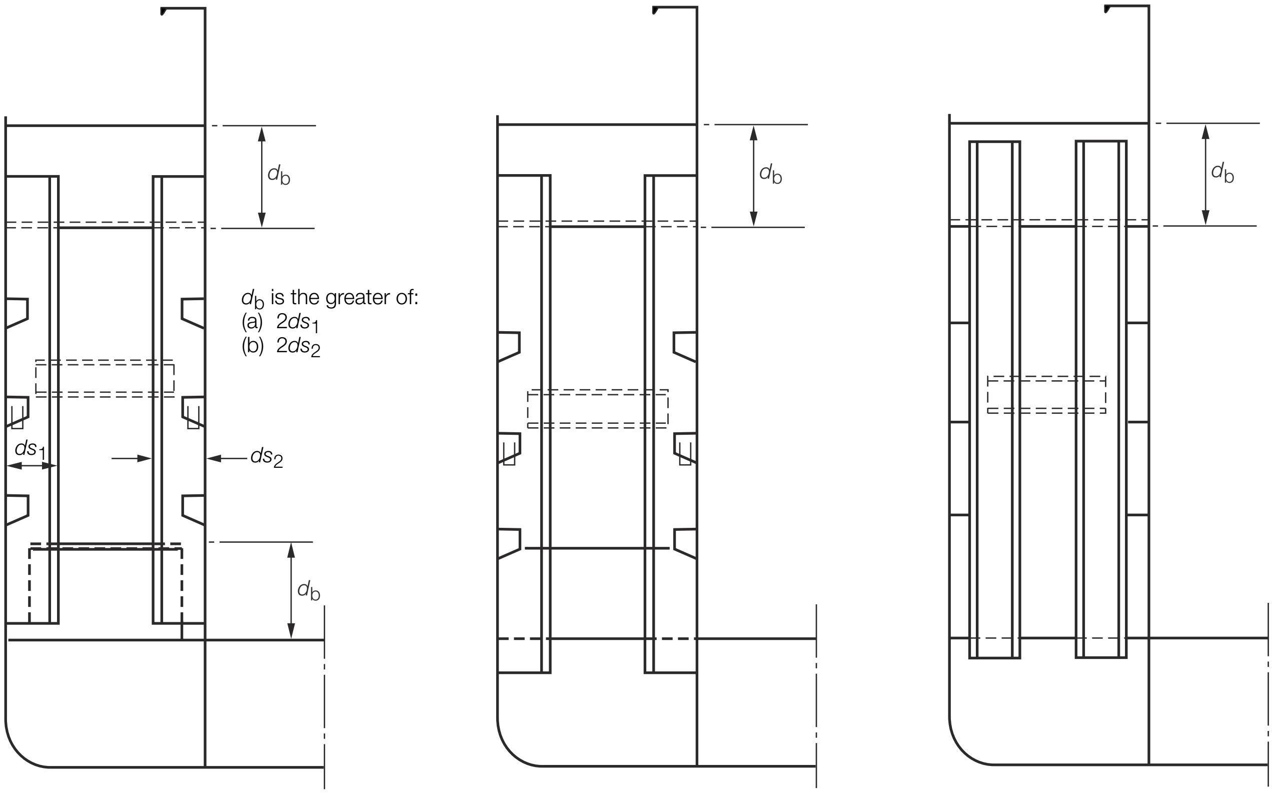


Figure 1.11.3 Arrangement for web frames

11.3.2 Web frames are to be fitted in line with plate floors and are generally to be constructed as indicated in *Figure 1.11.3 Arrangement for web frames*. The lower ends of the web frames may overlap the floors or are otherwise to be connected to the floors or tank top by means of brackets. At their upper ends, web frames are to be interconnected by means of brackets, *see also Figure 1.11.3 Arrangement for web frames*.

11.3.3 In addition to the web frames as required by *Pt 4, Ch 1, 11.3 Longitudinal framing 11.3.2*, plate webs are to be fitted not more than 8 m apart, *see also* Fig. *Figure 1.11.2 Arrangement of plate webs*(b). Manhole openings are to be provided in the plate webs to allow for inspection. Horizontal stiffeners are to be fitted to the plate webs spaced not more than twice the frame spacing apart. Plate webs with large access holes are to be additionally stiffened and their scantlings are to be verified by direct calculations.

11.3.4 As an alternative to the web frames required by *Pt 4, Ch 1, 11.3 Longitudinal framing 11.3.2*, plate webs in accordance with *Pt 4, Ch 1, 11.3 Longitudinal framing 11.3.3* may be fitted.

11.4 Longitudinal bulkhead

11.4.1 The scantlings of the longitudinal bulkhead are to comply with*Table 1.11.1 Double skin structure (General requirements)*.

11.4.2 Where the longitudinal bulkhead is not connected to the bottom shell but supported by the bottom floors, vertical stiffeners are to be fitted to the floors and connected to the inner bottom plating in line with the longitudinal bulkhead.

11.4.3 The ends of the longitudinal bulkheads are to be well scarfed into the ship's fore and aft structure.

11.5 Watertight sub-division

11.5.1 It is recommended that Owners consider subdividing the space between side shell and longitudinal bulkhead such that the ship remains afloat when one of the compartments becomes flooded.

11.5.2 For ships navigating on the Rhine or on European waterways with an overall length greater than 110 m, compliance with damage stability requirements are mandatory in accordance with the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN).

11.5.3 For ships carrying dangerous goods, *see also Pt 4, Ch 1, 12 Additional requirements for ships carrying dangerous goods*.

■ *Section 12*
Additional requirements for ships carrying dangerous goods

12.1 General

12.1.1 This Section applies to ships which are to be built in accordance with the additional requirements set out in Chapter 9, Section 9.1.0.80 of the ADN. Ships complying with the requirements of this Section will be eligible to receive the additional Class Notation in accordance with *Pt 4, Ch 1, 1.3 Class notation 1.3.5*.

12.1.2 The ADN are the regulations for the transport of dangerous goods on European waterways. The abbreviation **ADN** stands for:

Accord européen relatif au transport international
des marchandises **D**angereuses par voies de
Navigation intérieures.

12.1.3 The exemptions and derogations to the ADN , as authorised by the UNECE (United Nations Economic Commission for Europe) - Experts on ADN, may also be taken into consideration.

12.1.4 The structural and other arrangements of dry cargo ships for the carriage of dangerous goods in bulk, to be registered in, or to operate in countries with Regulations differing from ADN will receive appropriate special consideration if required by the relevant Authorities and/or desired by the Owner.

12.1.5 Although the contents of this Section take the ADN Regulations into account, the issue of an ADN Certificate on behalf of the Relevant Authorities requires full compliance with their Regulations.

12.1.6 For ease of reference, the relevant Parts of which the ADN consists are given hereunder:

Part 1	General provisions
Part 2	Classification (of dangerous goods)
Part 3	Lists of dangerous goods and special requirements
Part 4	Provisions concerning the use of packagings and tanks
Part 5	Consignment procedures
Part 6	Requirements for the construction and testing of packagings (including IBCs and large packagings) and tanks
Part 7	Requirements concerning loading, carriage, unloading and handling of cargo
Part 8	Provisions for the crew, certain equipment, operation and documentation
Part 9	Rules for construction.

12.1.7 For further details and information, reference is made to the above Parts of the ADN. For use together with this Chapter, special attention is drawn to the contents of Parts 2, 3, 7 and 9 of the ADN.

12.2 Dangerous goods

12.2.1 The following categories of dangerous goods are identified in Part 2 of the ADN:

Class 1	Explosive substances and articles
Class 2	Gases
Class 3	Flammable liquids
Class 4.1	Flammable solids, self-reactive substances and solid desensitized explosives
Class 4.2	Substances liable to spontaneous combustion
Class 4.3	Substances which, in contact with water, emit flammable gases
Class 5.1	Oxidising substances
Class 5.2	Organic peroxides
Class 6.1	Toxic substances
Class 6.2	Infectious substances
Class 7	Radioactive material
Class 8	Corrosive substances
Class 9	Miscellaneous dangerous substances and articles.

12.2.2 Table A as listed in Part 3 of the ADN contains the list of dangerous goods in numerical order (UN number or identification number). This Table also contains data concerning the permitted form of carriage in Inland Waterways vessels.

12.3 Limiting quantities of dangerous goods

12.3.1 Part 7 of the ADN contains requirements concerning the maximum quantities of dangerous goods of Classes 2, 3, 4.1, 4.2, 4.3, 5.1, 5.2, 6.1, 7, 8 and 9 which may be carried on one ship.

12.3.2 Ships intended to carry dangerous goods of Classes 2, 3, 4.1, 5.2, 6.1, 7, 8 or 9 – except those for which label No. 1 is prescribed in column (5) of Table A of *Pt 4, Ch 3, 2 Longitudinal strength* – in quantities exceeding those referred to in paragraph 7.1.4.1.1 of the ADN, shall also comply with the requirements of *Pt 4, Ch 1, 12.4 Structural requirements*, *Pt 4, Ch 1, 12.5 Arrangements*, *Pt 4, Ch 1, 12.6 Ventilation* and *Pt 4, Ch 1, 12.7 Stability* .

12.4 Structural requirements

12.4.1 The ship shall be built as a double-hull vessel with double hull spaces and a double bottom within the protected area.

12.4.2 The distance between the side shell and the cargo hold bulkheads shall not be less than 0,80 m.

12.4.3 The depth of the double bottom shall be not less than 0,50 m. The depth below a suction well may however be locally reduced to 0,40 m. When the distance of the bottom of the suction well is between 0,40 and 0,49 m from the baseline the horizontal cross-sectional area of the well shall not exceed 0,50 m^2. In all cases the volume of the well shall not exceed 0,12 m^3.

12.4.4 Regardless of statutory requirements relating to the width of walkways on deck, a reduction of the distance as per *Pt 4, Ch 1, 12.4 Structural requirements 12.4.2* to 0,60 m is permitted, provided that the following reinforcements will be provided:

(a) Where the vessel's sides are constructed according to the longitudinal framing system, the frame spacing shall not exceed 0,60 m. The longitudinals shall be supported by plate webs in line with the floors in the double bottom. Plate webs are to be provided with openings to enable proper inspection of the space. The webs are to be spaced not more than 1,80 m apart. This distance may be increased when the structure is strengthened accordingly;

(b) Where the vessel's sides are constructed according to the transverse framing system, either:

- two longitudinal side shell stringers shall be fitted. The distance between the two stringers and between the uppermost stringer and the deck at side shall not exceed 0,80 m. The depth of the stringers shall be at least equal to that of the transverse frames and the cross-section of the face plate shall be not less than 15 cm^2. The longitudinal stringers shall be supported by open plate webs in line with the plate floors in the double bottom and spaced not more than 3,60 m apart. The

transverse side shell frames shall be connected at the bilge by a bracket having a depth not less than 0,90 m and a thickness equal to the thickness of the floors;

or:

- open plate webs in line with the double bottom floors shall be arranged at each transverse frame;

(c) The upper deck shall be supported by transverse bulkheads or cross-ties spaced not more than 32 m apart. This requirement may be waived provided it is proven that the (additional) structure in the double hull is such that adequate transverse strength is achieved.

12.5 Arrangements

12.5.1 The bottom of the holds shall be such as to permit them to be cleaned and dried.

12.5.2 Cargo holds shall have no common bulkheads with fuel oil tanks.

12.5.3 The air pipes of all fuel oil tanks shall be led to 0,50 m above the open deck.

12.5.4 Means are to be provided to prevent the formation of sparks in the protected area.

12.5.5 Entrances to and openings of engine rooms and service spaces shall not face the cargo area.

12.5.6 Openings of the accommodation and wheel-house facing the cargo holds are to be provided with gastight closing appliances.

12.5.7 Exhausts shall be led into the open air either upwards through an exhaust pipe or through the shell plating. The exhaust outlet shall be located not less than 2,0 m from the cargo hold openings. The exhaust pipes of engines shall be arranged in such a way that the exhausts are led away from the vessel. The exhaust pipes shall not be located within the protected area.

12.6 Ventilation

12.6.1 Ventilation shall be provided for the accommodation and for service spaces.

12.6.2 Ventilation ducts for venting the hold(s) shall be positioned at the extreme ends of the hold(s) and extend down to not more than 50 mm above the bottom. The extraction of gases and vapours through the duct shall also be ensured in case of carriage of bulk cargoes.

12.6.3 If the ventilation ducts are removable they shall be suitable for the ventilator assembly and capable of being firmly fixed. Protection shall be ensured against bad weather and spray. An unobstructed intake of air shall be ensured during ventilation.

12.7 Stability

12.7.1 Attention is drawn to the ADN damage stability requirements. Verification of compliance with these regulations is usually dealt with by the National Authorities, but upon request, verification by the Society followed by issuing a statement of compliance can also be arranged.

■ *Section 13*
Direct calculation procedures

13.1 General

13.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

13.1.2 Where direct calculation is adopted as an alternative of scantlings derived by Rule formulae, or for the asessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads are to be submitted for approval together with the calculation.

13.2 Permissible stresses

13.2.1 In addition to the permissible stresses given in*Pt 3, Ch 4, 6 Hull bending strength* , the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 1.13.1 Maximum permissible stress in longitudinal continuous members, in N/mm²* .

(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 1.13.2 Maximum permissible stresses in local members, in N/mm²* .

13.2.2 Where finite plate element calculations are carried out, local peak stresses in excess of those given in *Pt 4, Ch 1, 13.2 Permissible stresses 13.2.1* will be specially considered.

Table 1.13.1 Maximum permissible stress in longitudinal continuous members, in N/mm²

Item	Local bending stress, σ_b	Combined bending stress, σ_c, *see* Note 1	Shear stress τ	Equivalent stress, σ_e, *see* Note 2
Bottom girders	$0{,}46\sigma_L$	$0{,}75\sigma_L$	$0{,}35\sigma_L$	$0{,}80\sigma_L$
Bottom longitudinals, Inner bottom longitudinals, Side shell longitudinals	$0{,}58\sigma_L$	$0{,}75\sigma_L$	$0{,}35\sigma_L$	$0{,}80\sigma_L$

where $\sigma_L = 235/k_L$

Note 1 The combined stress, σ_c, is the sum of the stress due to longitudinal bending and local loading.

Note 2. The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\left(\sigma_c^2 + 3\tau^2\right)}$

Table 1.13.2 Maximum permissible stresses in local members, in N/mm²

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *see* Note
Floors, non-continuous bottom girders, non-continuous deck girders, deck transverses, cantilever brackets	$0{,}53\sigma_O$	$0{,}35\sigma_O$	$0{,}75\sigma_O$

Note The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\left(\sigma_c^2 + 3\tau^2\right)}$

13.3 Structural requirements

13.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

13.3.2 In addition to the maximum permissible stresses given in this Section, the following minimum plating thickness requirements are to be complied with. The thickness of bottom, bilge and side shell plating amidships is to be not less than required by *Table 1.5.1 Shell envelope plating*. The minimum thickness of the deck plating and coaming plating is to be not less than required by *Table 1.4.1 Topside structure (general)*. Depending on the level of compressive stresses, additional buckling calculations may be required.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to ferries and roll on-roll off ships defined as follows:

(a) A ferry is a self-propelled ship, designed primarily for the carriage of vehicles and/or passengers on a regular scheduled service of short duration.
(b) A roll on-roll off ship is a self-propelled ship with machinery aft or a non-propelled ship, designed primarily for the carriage of vehicles and for cargo loaded/unloaded by wheeled vehicles.

1.1.2 The structural requirements of this Chapter are intended to cover the midship region, as defined in *Pt 3, Ch 3, 2.2 Definition of midship region* for ships having a length not exceeding 125 m, a ratio of length to depth not exceeding 33 and a ratio of breadth to depth not exceeding five.

1.1.3 Arrangements and scantlings forward and aft of the midship region are to comply with *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable. The remaining requirements of *Pt 3 Ship Structures (General)* are also to be complied with, as appropriate to the intended arrangements.

1.1.4 The scantlings and arrangements are to be as required in *Pt 3, Ch 1 General* as far as applicable or as specified otherwise in this Chapter.

1.1.5 For ferries carrying passengers, the requirements of *Pt 4, Ch 9 Passenger Ships* are also to be complied with so far as applicable.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a single flush deck or a multi-deck hull with a single or double bottom arrangement and a single skin side construction, *see Figure 2.1.1 Configuration with single flush deck or a multi-deck hull with a single or double bottom arrangement and a single skin side construction*, and for a basic structural configuration of a single deck hull with a long wide hatch opening, a double bottom and a double skin side construction, *see Figure 2.1.2 Configuration of a single deck hull with a long wide hatch opening, a double bottom and double skin side construction*.

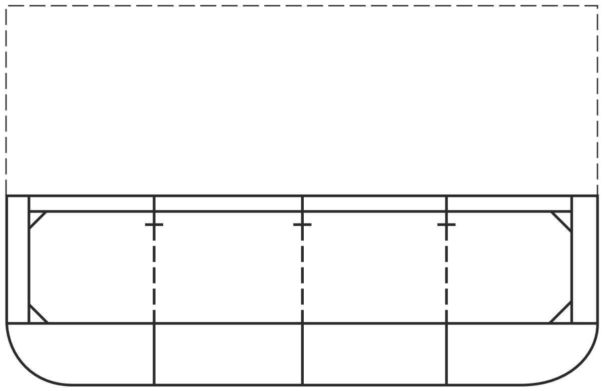


Figure 2.1.1 Configuration with single flush deck or a multi-deck hull with a single or double bottom arrangement and a single skin side construction

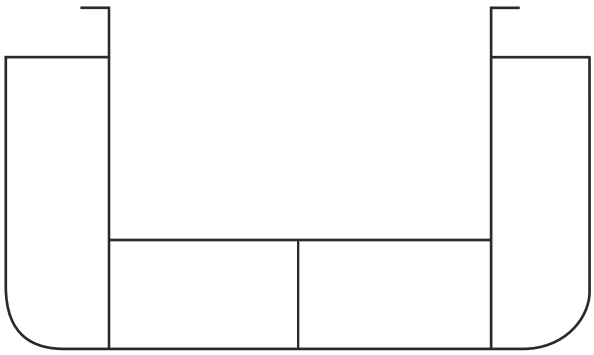


Figure 2.1.2 Configuration of a single deck hull with a long wide hatch opening, a double bottom and double skin side construction

1.2.2 Longitudinal or transverse framing may be adopted. Ships with a ratio of length to depth exceeding 25 or a length, *L*, over 70 m and having a double bottom, are generally to be constructed with longitudinal framing in the bottom. Alternatively, transverse framing may be adopted provided suitable longitudinal stiffening is fitted to the bottom plating.

1.2.3 The number and disposition of transverse bulkheads are to be as required by *Pt 3, Ch 7 Bulkheads*. Additional bulkheads many have to be fitted to provide for sufficient transverse strength of the ship. Web frames are to be fitted in line with deck transverses and floors, forming a ring system.

1.3 Class notation

1.3.1 Ships complying with the relevant requirements of this Chapter will be eligible to be classed ‘A1 I.W.W. ferry’, ‘A1 I.W.W. roll on-roll off ship’ or ‘A1 I.W.W. roll on-roll off barge’, whichever is applicable.

1.3.2 The Regulations for classification and assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made on the survey request form.

1.3.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.4 Information required

1.4.1 For the information required, *see Pt 3, Ch 1, 5 Information required*. In addition the following are to be supplied:

(a) Cargo loading on inner bottom and if applicable, also on hatchways and deck, *see Pt 3, Ch 3, 4 Design loading*.
(b) Details of wheeled vehicles to be used, *see Pt 3, Ch 9, 2.2 Loading*.
(c) The maximum pressure head in service on tanks, also details of any tanks interconnected with side tanks if fitted.
(d) Details of tanks which will be solely used for water ballast in the light condition and which will be empty in the loaded condition.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T and C_b as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

l = overall length of stiffening member, in metres, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

s = spacing of secondary stiffeners, i.e. frames, beams or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

S = spacing or mean spacing, of primary members, i.e. girders, transverses, webs, etc. in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*.

k_L = is given in *Pt 3, Ch 2, 1.3 Steel 1.3.2*

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

■ *Section 2* Longitudinal strength

2.1 General

2.1.1 The longitudinal strength of the ship is to comply with the requirements of *Pt 3, Ch 4 Longitudinal Strength* and for this purpose a ferry or roll on-roll off ship is to be considered as a Category 'O' ship.

2.1.2 The ratio of cargo compartment length, L, is to be taken as 0,73.

■ *Section 3* Topside structure and deck structure

3.1 General

3.1.1 The topside structure for ships of a structural configuration according to *Figure 2.1.2 Configuration of a single deck hull with a long wide hatch opening, a double bottom and double skin side construction* is to comply with *Pt 4, Ch 1, 4 Deck plating and continuous longitudinal hatch side coamings* .

3.1.2 Where a ship has a structural configuration according to *Figure 2.1.1 Configuration with single flush deck or a multi-deck hull with a single or double bottom arrangement and a single skin side construction*, the deck plating and deck supporting structure is to comply with the requirements of *Table 2.3.1 Deck plating and sheerstrake* and *Table 2.3.2 Deck supporting*

structure respectively, but in ships over 65 m in length, the thickness of deck plating may require to be increased to obtain the midship section modulus as required in *Pt 3, Ch 4 Longitudinal Strength*.

Table 2.3.1 Deck plating and sheerstrake

Item and Parameter	Longitudinal framing	Transverse framing
(1) Deck plating Thickness	The greater of: $t = (5,6 + 0,039L)\sqrt{ks}$ mm $t = 10s$ mm *See* Note 2 in *Table 2.3.2 Deck supporting structure*	The greater of: $t = (5,6 + 0,039L)\sqrt{ks}$ mm $t = 10s$ mm *See* Note 2 in *Table 2.3.2 Deck supporting structure*
(2) Sheerstrake thickness and width	As required by *Table 1.5.1 Shell envelope plating* in Ch 1,1, *see* Note	
Note For ships having a length L less than 40 m the sheerstrake may be replaced by the normal side shell plating, provided a suitable doubler plate or half round pipe is fitted in way.		

Table 2.3.2 Deck supporting structure

Item	Parameter	Requirements
(1) Deck beams	Modulus	$Z = 4,3 h_1 k s l_e{}^2 + 4$ cm^3
(2) Deck longitudinals	Modulus	$Z = (1,45 + 0,07 L_1) h_1 k s S l_e{}^2$ cm^3
(3) Deck girders	Modulus Inertia	$Z = (1,35 + 0,085 L_1)\, h_1 k S\, l_e{}^2$ cm^3 $I = \frac{2,3}{k} l_e Z$ cm^4
(4) Deck transverses	Modulus	$Z = 4,75 h_1 k S l_e{}^2$ cm^3
(5) Pillars	Cross- sectional area Minimal wall thickness of hollow pillars	$A_p = \frac{P}{1,26 - 4,2\frac{l}{r}}$ cm^2 The greater of: (a) $t = 0,033 d_p$ mm for tubular pillars $t = 0,056 b$ mm for square pillars (b) $t = 5$ mm
Symbols applying to *Table 2.3.1 Deck plating and sheerstrake* and *Table 2.3.2 Deck supporting structure*		

L, *B*, *D*, *S*, *s*, l_e, *Z*, *I*, *k* and *t* are as defined in *Pt 4, Ch 2, 1.5 Symbols and definitions 1.5.1*		
a_1	=	total area of deck longitudinals, in cm^2
b	=	breadth of side of a hollow rectangular pillar, in mm
d_p	=	mean diameter of tubular pillars, in mm
h_1	=	head on deck, in metres, as defined in *Pt 3, Ch 3, 4 Design loading*
l	=	overall length of pillar, in metres
r	=	least radius of gyration of pillar cross-section, in mm, and may be taken as:
r	=	$10\sqrt{\frac{I_p}{A_p}}$
A_p	=	cross-sectional area of pillar, in cm^2
C_1	=	$1 + 3\left(\frac{s}{S}\right)^2$ where $\frac{s}{S}$ is the ratio of the unstiffened deck panel under consideration
I_p	=	least moment of inertia of cross-section, in cm^4
L_1	=	*L*, but is to be not less than 40 m, nor more than 100 m
M	=	the greater of *MS* and *MH*
MH	=	maximum design hogging moment, in tm, *see Pt 3, Ch 4 Longitudinal Strength*
MS	=	maximum design hogging moment, in tm, *see Pt 3, Ch 4 Longitudinal Strength*
P	=	load supported by the pillar, in tonne-f
Note 1 The deck structure is also to comply with the requirements of *Pt 3, Ch 9, 2 Decks loaded by wheeled vehicles* for the parts of the deck used by wheeled vehicles. **Note** 2 Where the head, in metres, h_1, exceeds 3,5 m this thickness is to be increased by the factor: $\sqrt[3]{\frac{h_1}{3,5}}$		

3.1.3 The parts of the deck used by wheeled vehicles are also to comply with the requirements of *Pt 3, Ch 9, 2 Decks loaded by wheeled vehicles*.

3.2 Deck plating

3.2.1 Where hatch openings are made in the deck plating, compensation will be required for the material cut out. However, no compensation need be fitted if the loss of sectional area has already been taken into consideration in calculating the actual midship hull section modulus. Plate panels, in which openings are cut, are where necessary, to be adequately stiffened against compression.

3.3 Deck supporting structure

3.3.1 Scantlings given in *Table 2.3.2 Deck supporting structure* are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

3.3.2 Deck girders and transverses may be fitted in conjunction with load-bearing bulkheads or pillars for support of deck beams and deck longitudinals. Where tracked vehicles are proposed, girders are to be fitted under the trackways.

3.3.3 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

3.4 Sheerstrakes

3.4.1 The sheerstrake is to comply with the requirements of *Table 2.3.1 Deck plating and sheerstrake*.

3.5 Truss arrangements

3.5.1 Truss arrangements comprising top and bottom girders or transverses in association with pillars and diagonal bracing, may be fitted to support the bottom and deck structure. The diagonal members are generally to have angles of inclination with the horizontal of 45° and a cross-sectional area of not less than 50 per cent of the adjacent pillar.

3.6 Vehicle ramps

3.6.1 The strength of ramps forming an integral part of the ship's structure, and of ramps used as watertight means of closing, is to be equivalent to the surrounding ship's structure. The strength of the ramps is also to be verified for vehicle loading and to comply with *Pt 3, Ch 9, 2 Decks loaded by wheeled vehicles*.

3.6.2 Where hinges are provided for support of ramps, the ship's structure in way is to be suitably reinforced.

■ *Section 4*
Single bottom structure

4.1 General

4.1.1 The requirements of *Pt 4, Ch 1, 6 Single bottom structure* are to be applied together with the requirements of this Section. Additionally, scantlings for structural members of longitudinally framed single bottoms are given in *Table 2.4.1 Longitudinally framed single bottom*. The scantlings of longitudinals are based on end connections in accordance with*Pt 3, Ch 10, 3 Secondary member end connections*.

Table 2.4.1 Longitudinally framed single bottom

Item	Parameter	Requirement
(1) Girders	Web and face plate thickness	$(0{,}01d_w + 3)\sqrt{k}$ mm
	Width of face plate	b_f = 100 mm
(2) Bottom transverses	Modulus	$Z = 7D_1kSl_e^{\ 2}$ cm^3
(3) Bottom longitudinals	Modulus	$Z= (2 + 0{,}1L_1)D_1\ ksl_e^{\ 2}$ cm^3
Symbols		
L, B, D, T, S, s, l_e, Z, l, k and t are as defined in *Pt 4, Ch 2, 1.5 Symbols and definitions 1.5.1* b_f = width of face plate, in mm d_w = web depth of floor or girder, in mm D_1 = D but need be taken not greater than T + 0,4 m L_1 = L but is to be not less than 40 m, nor more than 100 m		

4.2 Girders (longitudinal framing)

4.2.1 A centreline girder is generally required in ships with a breadth, *B*, of more than 6 m. Alternatively, side girders may be fitted under pillars supporting the deck structure, but generally adequate support for docking purposes is to be provided on the centreline. Girders are to have the same depth as transverses.

4.3 Transverses (longitudinal framing)

4.3.1 Transverses are to be fitted at a spacing not exceeding 2,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the transverses at every fourth longitudinal. In between the transverses, brackets are to be fitted connecting the transverse side frames to the outer bottom longitudinal.

4.3.2 Where transverses support point loads, the required section modulus and shear area are to be verified by direct calculation. For permissible stresses, *see Pt 4, Ch 2, 7 Direct calculation procedures*.

■ *Section 5* Double bottom structure

5.1 General

5.1.1 The requirements of *Pt 4, Ch 1, 7 Double bottom structure* are to be applied together with the requirements of this Section.

5.1.2 Where the tank top is to be used for the carriage of wheeled vehicles, the depth of the double bottom is to be at least 650 mm and the space is to be accessible. The minimum thickness of floors and inner bottom longitudinals is to be 7 mm and the inner bottom plating and bottom structure is also to comply with the requirements of*Pt 3, Ch 9, 2 Decks loaded by wheeled vehicles*.

5.2 Floors

5.2.1 Where floors support point loads, with or without the addition of uniformly distributed loads, the required section modulus and shear area are to be verified by direct calculation. For permissible stresses, *see Pt 4, Ch 2, 7 Direct calculation procedures*.

■ *Section 6* Side shell structure

6.1 General

6.1.1 This Section covers the arrangements and requirements for a transversely or longitudinally framed side shell structure in single and double skin ships.

6.1.2 The scantlings of the double skin structure, except side shell plating, are to comply with *Table 2.6.1 Side shell structure (single skin ships)*. The scantlings given in this Table are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with*Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

Table 2.6.1 Side shell structure (single skin ships)

Item	Parameter	Requirement
(1) Side frame	Modulus	$Z = 7h_f k s l_e^{\,2}$ cm^3
(2) Side longitudinals	Modulus	$Z = (4{,}6 + 0{,}0342L_1)\, h_f\, k s\, l_e^{\,2}$ cm^3
(3) Side transverses	Modulus	$Z = 10h_f\, kSl_e^{\,2}$ cm^3 *See* Note
(4) Stringers	Modulus	$Z = 6{,}6h_f kS\, l_e^2$ cm^3
(5) Webs supporting stringers and girders	Modulus	Z is to be determined from calculations using a stress of $98/k$ N/mm^2 assuming fixed ends, in association with a head, h_f. *See* Note
Symbols		
L, S, s, l_e, Z, k and l are as defined in *Pt 4, Ch 2, 1.5 Symbols and definitions 1.5.1* h_f = the vertical distance, in metres, from the middle of the effective length of the stiffening member under consideration to the deck at side or to a line at T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1, whichever is the lesser, but is to be taken as not less than 2,0 m L_1 = L but is to be not less than 40 m, nor more than 100 m		
Note The section modulus of side transverses or webs at top and bottom is to be not less than half the section modulus of the bottom and deck transverses in way.		

6.1.3 The side shell structure for double skin ships is to comply with the requirements of *Pt 4, Ch 1, 11 Double skin structure*.

6.2 Web frames

6.2.1 Web frames forming a ring system with floors or bottom transverses and deck transverses, are to be fitted at a spacing not exceeding 8 m.

6.3 Frames

6.3.1 When the side frames are supported by an effective system of stringers and web frames, the Rule section modulus of side frames, ascertained ignoring the stringers, may be reduced by 30 per cent.

■ *Section 7*
Direct calculation procedures

7.1 General

7.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

7.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulæ, or for the assessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads are to be submitted for approval together with the calculation.

7.2 Permissible stresses

7.2.1 In addition to the permissible stresses given in *Pt 3, Ch 4, 6 Hull bending strength* the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 2.7.1 Maximum permissible stresses in longitudinal continuous members, in N/mm²* .
(b) For structural members not included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 2.7.2 Maximum permissible stresses in local members, in N/mm²* .

Table 2.7.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2

Item	Local bending stress , σ_b	Combined bending stress, σ_c, *see* Note 1	Shear stress, τ	Equivalent stress, σ_e, *see* Note 2
Bottom girders Deck girders	0,46σ_L	0,75σ_L	0,35σ_L	0,80σ_L
Bottom longitudinals Inner bottom longitudinals Deck longitudinals Side shell longitudinals	0,58σ_L	0,75σ_L	0,35σ_L	0,80σ_L

where $\sigma_L = k_L$

Note 1. The combined stress σ_c is the sum of the stresses due to longitudinal bending and local loading.

Note 2. The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Table 2.7.2 Maximum permissible stresses in local members, in N/mm^2

Item	Bending stress, σ_b	Shear stress,τ	Equivalent stress, σ_e, *see* Note
Floors, non-continuous bottom girders, non-continuous deck girders, deck transverses,	0,53σ_O	0,35σ_O	0,75σ_O
Web frames	0,42σ_O	0,35σ_O	0,69σ_O
Frames, bottom transverse	0,48σ_O	0,35σ_O	0,73σ_O
Deck beams	0,58σ_O	0,35σ_O	0,79σ_O

Note The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$

7.3 Structural requirements

7.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

7.3.2 In addition to the maximum permissible stresses given in *Pt 4, Ch 2, 7.2 Permissible stresses*, the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see Pt 3, Ch 5, 2 Hull envelope plating*.
(b) The thickness of bilge plating amidships is to be 2 mm more than the bottom plating in way.
(c) The minimum thickness of the deck plating is to be not less than the thickness of deck plating at ends, *see Pt 3, Ch 5, 2 Hull envelope plating*.
(d) Depending on the level of compressive stresses, additional buckling calculations may be required.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to ships which are generally being towed and/or pushed or carried alongside another ship and to self-propelled ships with machinery aft, intended for the carriage of non-perishable cargo on deck.

1.1.2 The structural requirements of this Chapter are intended to cover the midship region (0,5*L*), as defined in *Pt 3, Ch 3, 2.2 Definition of midship region* for ships having a length not exceeding 125 m, a ratio of length to depth not exceeding 35 and a ratio of breadth to depth not exceeding seven.

1.1.3 Arrangements and scantlings forward and aft of the midship region are to comply with *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable, the remaining requirements of *Pt 3 Ship Structures (General)* are also to be complied with as appropriate to the intended arrangements.

1.1.4 The arrangements are to be as required in *Pt 4, Ch 1 Dry Cargo Ships*, as far as applicable, or as specified otherwise in this Chapter.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a single flush deck hull with only small access openings, and with single bottom and single skin side construction.

1.2.2 Longitudinal or transverse framing may be adopted, or a combination thereof. For ships over 50 m in length, it is recommended that a longitudinal framing system in bottom and deck be used.

1.2.3 The number and disposition of transverse bulkheads are to be as required by *Pt 3, Ch 7 Bulkheads* but additional transverse bulkheads may have to be fitted to provide for sufficient transverse strength of the ship. It is recommended that longitudinal bulkheads be fitted to support the bottom and deck structure

1.3 Class notation

1.3.1 Ships complying with the requirements of this Chapter will be eligible to be classed:

‘A1 I.W.W. pontoon’, or

‘A1 I.W.W. pontoon, self propelled'.

1.3.2 The Regulations for classification and assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made on the survey request form.

1.3.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.4 Information required

1.4.1 For the information required, *see Pt 3, Ch 1, 5 Information required*. In addition the following are to be supplied:

(a) Details of cargo loading on deck, *see Pt 3, Ch 3, 4 Design loading*.
(b) The maximum pressure head in service on tanks.
(c) Details of tanks which will be solely used for water ballast.
(d) Details of wheeled vehicles, when used for loading/ unloading of the cargo.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, *B*, *D* and *T* are as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

k_L is given in *Table 2.1.1 Values of* K_L

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

l = overall length of stiffening member, in metres, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

s = spacing of secondary stiffeners, i.e. frames, beams or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs, etc. in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*.

■ *Section 2*
Longitudinal strength

2.1 General

2.1.1 The longitudinal strength of the ship is to comply with the requirements of *Pt 3, Ch 4 Longitudinal Strength* and, for this purpose, a pontoon is to be considered as a Category ‘O’ ship.

2.1.2 The ratio of cargo compartment length, *L*, is to be taken as 0,73.

■ *Section 3*
Hull envelope plating

3.1 General

3.1.1 The requirements of *Pt 4, Ch 1, 5 Hull envelope plating* are to be applied together with the requirements of this Section. The thickness of hull envelope plating amidships is to be not less than required in *Table 3.3.1 Hull envelope plating*, but for ships over 65 m in length, the thickness of the bottom plating and deck plating may require to be increased to obtain the midship section modulus required in *Pt 3, Ch 4 Longitudinal Strength*.

Table 3.3.1 Hull envelope plating

<table>
<tr><td>Item and parameter</td><td colspan="2">Required minimum scantlings</td></tr>
<tr><td>(1) Plate keel
Breadth
Thickness</td><td colspan="2">
0,1B m but not less than 0,75 m
As bottom plating t_b
When there is a rise of floor, the thickness is to be increased by 1 mm</td></tr>
<tr><td rowspan="2">(2) Bottom plating Thickness</td><td>Longitudinal framing</td><td>Transverse framing</td></tr>
<tr><td>The greater of :
$t_b = (5,6 + 0,054L)\sqrt{ks}$mm
$t_b = 10s$ mm</td><td>The greater of :
$t_b = (5,6 + 0,054L)\sqrt{ks}$mm
$t_b = 10s$ mm</td></tr>
<tr><td>(3) Bilge plating
Thickness</td><td colspan="2">Longitudinal and transverse framing. $t = t_b + 2$ mm</td></tr>
<tr><td>(4) Bilge chine bars
(a) Round bars Diameter
(b) Square bars Width
(c) Angle bars Flange thickness</td><td colspan="2">
$3t_b$ mm but not less than 30 mm
$3t_b$ mm but not less than 30 mm
$t = 2t_b$ mm</td></tr>
<tr><td>(5) Side shell plating Thickness</td><td colspan="2">The greater of :
$t_b = (5,6 + 0,054L)\sqrt{ks}$ mm
$t_b = 10s$ mm</td></tr>
<tr><td>(6) Sheerstrake
Width
Thickness</td><td colspan="2">
0,1 D m but not less than 0,2 m
$t = t_d$ plus 5 mm
See note 1</td></tr>
<tr><td rowspan="2">(7) Deck Plating thickness</td><td>Longitudinal framing</td><td>Transverse framing</td></tr>
<tr><td>The greater of:
$t_b = (5,6 + 0,039L)\sqrt{ks}$mm
$t_b = 10s$ mm
t = 6 mm
See note 2</td><td>The greater of:
$t_b = (5,6 + 0,039L)\sqrt{ks}$mm
$t_b = 10s$mm
t = 6 mm
See note 2</td></tr>
<tr><td colspan="3">Symbols</td></tr>
<tr><td colspan="3">L, B, D, T, S, s, k and t are as defined in Pt 4, Ch 3, 1.5 Symbols and definitions 1.5.1
a_1 = total area of bottom or deck longitudinals, as applicable, in cm^2
t_b = thickness of bottom plating, in mm
t_d = thickness of deck plating connected to the sheerstrake, in mm</td></tr>
</table>

C_1	=	$1 + 3\left(\frac{s}{S}\right)^2$ where $\frac{s}{S}$ is the ratio of the unstiffened plate panel under consideration
M	=	the greater of M_S and M_H
M_H	=	maximum design hogging bending moment, in tm, *see Pt 3, Ch 4 Longitudinal Strength*
M_S	=	maximum design sagging bending moment, in tm, *see Pt 3, Ch 4 Longitudinal Strength*

Note 1. Where a substantial welded steel rubbing bar is fitted, the sheerstrake may be of the same thickness as the side shell in way.

Note 2. Where the head on deck in metres, h_1, as defined in *Pt 3, Ch 3, 4 Design loading* exceeds 3,5 m, this thickness is to be increased by the factor

$$\sqrt[3]{\frac{h_1}{3,5}}$$

3.2 Deck plating

3.2.1 Where openings are made in the deck plating for access, the deck plating in way is, generally, to be increased in thickness to compensate for the material cut out. However, no compensation need be fitted if the loss of sectional area has already been taken into consideration when calculating the actual midship hull section modulus.

3.2.2 Circular openings in deck of a diameter of 150 mm or less need not be compensated, provided they are situated well clear of other openings and the area cut out transversely over the deck does not exceed three per cent of the total area.

3.2.3 Plate panels, in which openings are cut are, where necessary, to be adequately stiffened against compression.

3.2.4 Areas of the deck used by wheeled vehicles are also to comply with the requirements of *Pt 3, Ch 9, 2 Decks loaded by wheeled vehicles*.

■ *Section 4*
Hull envelope framing (longitudinal or transverse framing)

4.1 General

4.1.1 The requirements of *Pt 4, Ch 1, 11 Double skin structure* are to be applied together with the requirements of this Section. The scantlings of the hull structural members are to comply with *Table 3.4.1 Hull envelope framing* .

Table 3.4.1 Hull envelope framing

Item	Parameter	Requirements
(1) Floors	Modulus Web depth Web thickness	$Z = 6,6 \times k \times D_1 \times s \times l_e^{\ 2}$ cm^3 $d_w \geq 30B$ mm $t = (0,01d_w + 2)\sqrt{k}$ mm
(2) Bottom longitudinals	Modulus Inertia	$Z = (2 + 0,1L_1) \times D_1 \times k \times s \times l_e^{\ 2}$ cm^3 $I = \frac{2,3}{k} \times l_e \times Z$ cm^4
(3) Bottom transverses	Modulus	$Z = 7 \times D_1 \times k \times S \times l_e^{\ 2}$ cm^3
(4) Bottom centre girder	Web and face plate thickness Minimum flange width	$t = (0,01d_w + 3)\sqrt{k}$ mm $b_f = 100$ mm
(5) Bottom side girders	Scantlings	As centre girders
(6) Side frames	Modulus	$Z = 7 \times h_f \times k \times s \times l_e^{\ 2}$ cm^3 *See* Note 1
(7) Side longitudinals	Modulus	$Z = (4,6 + 0,0342L_1) \times h_f \times k \times s \times l_e^{\ 2}$ cm^3
(8) Side transverses	Modulus	$Z = 10 \times h_f \times k \times S \times l_e^{\ 2}$ cm^3 *See* Note 1
(9) Stringers	Modulus	$Z = 6,6 \times h_f \times k \times S \times l_e^{\ 2}$ cm^3
(10) Web supporting stringers and girders	Modulus	Z is to be determined from calculations using a stress of $98/k$ N/mm^2, assuming fixed ends, in association with a head, h_f *See* Note 1
(11) Deck beams	Modulus	$Z = 4,3 \times h_1 \times k \times s \times l_e^{\ 2} + 4$ cm^3
(12) Deck longitudinals	Modulus Inertia	$Z = (1,45 + 0,07L_1) \times h_1 \times k \times s \times l_e^{\ 2}$ cm^3 $I = \frac{2,3}{k} \times l_e \times Z$ cm^4
(13) Deck girders	Modulus Inertia	$Z = (1,35 + 0,085L_1) \times k \times S \times h_1 \times l_e^{\ 2}$ cm^3 $I = \frac{2,3}{k} \times l_e \times Z$ cm^4
(14) Deck transverses	Modulus	$Z = 4,75 \times h_1 \times k \times S \times l_e^{\ 2}$ cm^3
(15) Pillars	Cross-sectional area Minimum wall thickness of hollow pillars	$A_p = \dfrac{P}{1,26 - 4,2\frac{l}{r}}$ cm^2 The greater of: (a) $t = 0,033d_p$ mm for tubular pillars $t = 0,056b$ mm for square pillars (b) $t = 5$ mm
Symbol		
L, *B*, *D*, *T*, *S*, *s*, l_e, *Z*, *I*, *k* and *t* are as defined in *Pt 4, Ch 3, 1.5 Symbols and definitions 1.5.1* b = breadth of side of a hollow square pillar, in mm		

b_f	=	minimum flange width of the bottom centre girder or bottom side girders as applicable
d_p	=	mean diameter of tubular pillars, in mm
d_w	=	depth of web plate, in mm
h_f	=	the vertical distance, in metres, from the middle of the effective length of the stiffening member under consideration to the deck at side or to a line at T + 0,4 m, whichever is the lesser, but is to be taken as not less than 0,25D m
h_1	=	head on deck, in metres, as defined in *Pt 3, Ch 3, 4 Design loading*, but is to be taken as not less than 1,5 m
l	=	overall length of pillar, in metres
r	=	least radius of gyration of pillar cross-section, in mm, and may be taken as:
r	=	$10\sqrt{\dfrac{I_p}{A_p}}$
A_p	=	cross-sectional area of pillar, in cm^2
D_1	=	D, but need not be taken greater than T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1
I_p	=	least moment of inertia of cross-section, in cm^4
L_1	=	L but is to be not less than 40 m, nor more than 100 m
P	=	load supported by the pillar, in tonne-f

Note 1. The section modulus of side transverses and frames connecting deck and bottom transverses at top and bottom is to be not less than half the section modulus of the bottom and deck transverse whereto connected.

Note 2. In case the scantlings of longitudinal members result in an appreciable excess in the hull midship section modulus as required by *Pt 3, Ch 4 Longitudinal Strength* for the ship type concerned, a reduction in the modulus of the relevant members may be applied provided the permissible combined bending stress and the permissible local bending stress are not exceeded. For permissible stresses, *see Pt 4, Ch 3, 5 Direct calculation procedures*.

4.1.2 Scantlings given in *Table 3.4.1 Hull envelope framing* are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected inaccordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

4.2 Longitudinal framing system

4.2.1 A centreline girder is generally required in ships with a breadth, B, of more than 6 m. Alternatively, side girders may be fitted under pillars supporting the deck structure, but generally adequate support for docking purposes is to be provided on the centreline. Girders are to have the same depth as transverses.

4.2.2 Longitudinal stiffening members are to be supported by transverses arranged to form ring systems. Their spacing is not to exceed 3,5 m.

4.2.3 The depth of transverses is generally to be not less than twice the depth of the slot for the longitudinals.

4.2.4 Transverses fitted on the inboard face of longitudinals are to comply with the requirements of *Pt 3, Ch 3, 3 Structural idealisation* and associated *Figure 3.3.4 Rolled or built sections fitted on top of supported stiffening members* .

4.2.5 Longitudinals are generally to be carried through transverse bulkheads. If they stop at transverse bulkheads, brackets are to be fitted inter-connecting the longitudinals. *See also Pt 3, Ch 10, 3.3 Basis for calculation of bracket connections 3.3.1.(c)*.

4.2.6 Scallops in longitudinals may not be fitted in way of end connections, crossings with transverses or tripping brackets.

4.3 Transverse framing system

4.3.1 Floors, frames and deck beams are to be fitted at every frame. Girders may be fitted to reduce the unsupported span of floors and deck beams.

4.3.2 When side frames are supported by an effective system of stringers and web frames, the Rule section modulus of the frames (ignoring the stringers) may be reduced by 30 per cent.

4.4 Combination system

4.4.1 Where a combination framing system is adopted (shell transverse and bottom and deck longitudinal framing) a transverse ring system as indicated in *Pt 4, Ch 3, 4.2 Longitudinal framing system 4.2.2* is to be fitted.

4.4.2 Brackets at the top and bottom of side frames are to extend to the adjacent deck or bottom longitudinal to which they are to be connected.

4.5 Deck supporting structure

4.5.1 Deck girders and transverses may be fitted in conjunction with load-bearing bulkheads or pillars, for support of deck beams and deck longitudinals.

4.5.2 Effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Tripping brackets or equivalent are to be fitted to the transverse or girder web plates in way of the pillar. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

4.5.3 Areas of the deck used by wheeled vehicles are also to comply with the requirements of *Pt 3, Ch 9, 2 Decks loaded by wheeled vehicles*.

4.5.4 The scantlings of the deck supporting structure forward and aft of the midship region are to be based on the actual deck loading but the head on deck, h_1, is to be taken as not less than 1,5 m.

4.6 Truss arrangements

4.6.1 Truss arrangements, comprising top and bottom girders or transverses in association with pillars and diagonal bracing, may be fitted to support the bottom and deck structure. The diagonal members are generally to have angles of inclination with the horizontal of 45° and a cross-sectional area of not less than 50 per cent of the adjacent pillar.

■ *Section 5* Direct calculation procedures

5.1 General

5.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

5.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads, are to be submitted for approval together with the calculation.

5.2 Permissible stresses

5.2.1 In addition to the permissible stresses given in *Pt 3, Ch 4, 6 Hull bending strength* the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 3.5.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2* .

(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 3.5.2 Maximum permissible stresses in local members, in N/mm^2* .

Table 3.5.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2

Item	Local bending stress , σ_b	Combined bending stress, σ_c, *see* Note 1	Shear stress , τ	Equivalent stress , σ_e, *see* Note 2
Bottom girders Deck girders	0,46σ_L	0,75σ_L	0,35σ_L	0,80σ_L
Bottom longitudinals Inner bottom longitudinals Deck Longitudinals Side shell longitudinals	0,58σ_L	0,75σ_L	0,35σ_L	0,80σ_L

where $\sigma_L = 235/k_L$

Note 1. The combined stress σ_c is the sum of the stresses due to longitudinal bending and local loading.

Note 2. The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Table 3.5.2 Maximum permissible stresses in local members, in N/mm^2

Item	Bending stress, σ_b	Sheer stress, τ	Equivalent stress, σ_e, *see* Note
Floors, non-continuous bottom girders, non-continuous deck girders, deck transverses	0,53σ_O	0,35σ_O	0,75σ_O
Web frames	0,42σ_O	0,35σ_O	0,69σ_O
Frames, bottom transverses	0,48σ_O	0,35σ_O	0,73σ_O
Deck beams	0,58σ_O	0,35σ_O	0,79σ_O

Note The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$

5.3 Structural requirements

5.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

5.3.2 In addition to the maximum permissible stresses given in *Pt 4, Ch 3, 5.2 Permissible stresses* the following minimum plating thickness requirements are to be complied with. The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see Pt 3, Ch 5, 2 Hull envelope plating*. The thickness of the bilge plating amidships is to be 2 mm more than the bottom plating in way. The minimum thickness of the deck plating is to be not less than the thickness of deck plating at ends, *see Pt 3, Ch 5, 2 Hull envelope plating*. Depending on the level of compressive stresses, additional buckling calculations may be required.

■ *Section 1* General

1.1 Application and definitions

1.1.1 This Chapter applies to propelled and non-propelled tankers of Type G, C and N intended for the carriage of dangerous liquids in bulk.

1.1.2 Most of the definitions hereunder have been derived from Part 1 of the ADN. Only the ADN definitions relevant to this Chapter have been included. A number of ADN definitions have been reworded. For a complete overview of all ADN definitions, reference is made to Part 1 of the ADN:

1.1.3 **Accommodation** means spaces intended for the use of persons normally living on board, including galleys, food stores, lavatories, washrooms, bathrooms, laundries, halls, alleyways, etc. but excluding the wheelhouse.

1.1.4 **Cargo area** means the whole of the following spaces (*see Figure 4.1.1 Above deck cargo area for various tank vessels*);

1.1.5 **Cargo area (additional part above deck) (when antiexplosion protection is required, comparable to zone 1)** means the spaces not included in the main part of cargo area above deck comprising 1,00 m radius spherical segments centred over the ventilation openings of the cofferdams and the service spaces located in the cargo area part below the deck and 2,00 m spherical segments centred over the ventilation openings of the cargo tanks and the opening of the pump rooms;

1.1.6 **Cargo area (main part above deck) (when anti-explosion protection is required – comparable to zone 1)** means the space which is bounded:

- at the sides, by the shell plating extending upwards from the deck's sides;
- fore and aft, by planes inclined at 45° towards the cargo area, starting at the boundary of the cargo area part below deck;
- vertically, 3,00 m above the deck;

1.1.7 **Cargo area (part below deck)** means the space between two vertical planes perpendicular to the centre-line plane of the vessel, which comprises cargo tanks, hold spaces, cofferdams, double-hull spaces and double bottoms; these planes normally coincide with the outer cofferdam bulkheads or hold end bulkheads. Their intersection line with the deck is referred to as the boundary of the cargo area part below deck;

1.1.8 **Cargo tank (when anti-explosion protection is required, comparable to zone 0)** means a tank intended for the carriage of dangerous or non-dangerous liquids. The cargo tank can either be integral with the hull structure of the ship or can consist of a separate tank independent from the ship's hull.

1.1.9 **Cargo tank (open or closed type).** The following basic types of cargo tanks can be discerned:

- 'Open type' cargo tanks are tanks in which the cargo is carried at atmospheric pressure by means of a ventilation system open to the air.
- 'Closed type' cargo tanks are tanks in which the cargo is shut-off from the open air during carriage and which are protected against overpressure and unacceptable vacuum.

1.1.10 **Classification of zones** (*see* IEC publication 79-10, the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN)):

- Zone 0: areas in which dangerous explosive atmospheres of gases, vapours or sprays exist permanently or during long periods;

- Zone 1: areas in which dangerous explosive atmospheres of gases, vapours or sprays are likely to occur occasionally;
- Zone 2: areas in which dangerous explosive atmospheres of gases, vapours or sprays are likely to occur rarely and, if so, for short periods only.

1.1.11 **Cofferdam** (when anti-explosion protection is required, comparable to zone 1) means an athwartship compartment which is bounded by watertight bulkheads and which can be inspected. The cofferdam shall extend over the whole area of the end bulkheads of the cargo tanks. The bulkhead not facing the cargo area shall extend from one side of the vessel to the other and from the bottom to the deck in one frame plane.

1.1.12 **Flash-point** means the lowest temperature of a liquid at which its vapours form a flammable mixture with air.

1.1.13 **Identification number** means the number for identifying a substance to which no UN number has been assigned or which cannot be classified under a collective entry with a UN number. These numbers have four figures beginning with 9.

1.1.14 **Maximum working pressure** means the maximum pressure occurring in a cargo tank or a residual cargo tank during operation. This pressure equals the opening pressure of high velocity vent valves.

1.1.15 **Opening pressure** means the pressure referred to in a list of substances at which the high velocity vent valves open.

1.1.16 **Packing group** means a group to which, for packing purposes, certain substances may be assigned in accordance with their degree of danger. The packing groups have the following meanings which are explained more fully in Part 2 of the ADN:

- Packing group I: Substances presenting high danger;
- Packing group II: Substances presenting medium danger; and
- Packing group III: Substances presenting a lower danger.

1.1.17 **Pressures.** For tanks, all kinds of pressures (e.g. working pressure, opening pressure of the high velocity vent valves, test pressure) shall be expressed as gauge pressures in kPa (bar); the vapour pressure of substances, however, shall be expressed as an absolute pressure in kPa (bar).

1.1.18 **Pressure tank** means a tank designated and approved for a working pressure > 400 kPa (4 bar).

1.1.19 **Tanker.** A ship which has been specially designed and constructed for the carriage of liquids or gases in bulk.

1.1.20 **Test pressure** means the pressure at which a cargo tank, a residual cargo tank, a cofferdam or the loading and unloading pipes shall be tested prior to being brought into service for the first time and subsequently regularly within prescribed times.

1.1.21 **UN number** means the four-figure identification number of the substance or article taken from the United Nations Model Regulations.

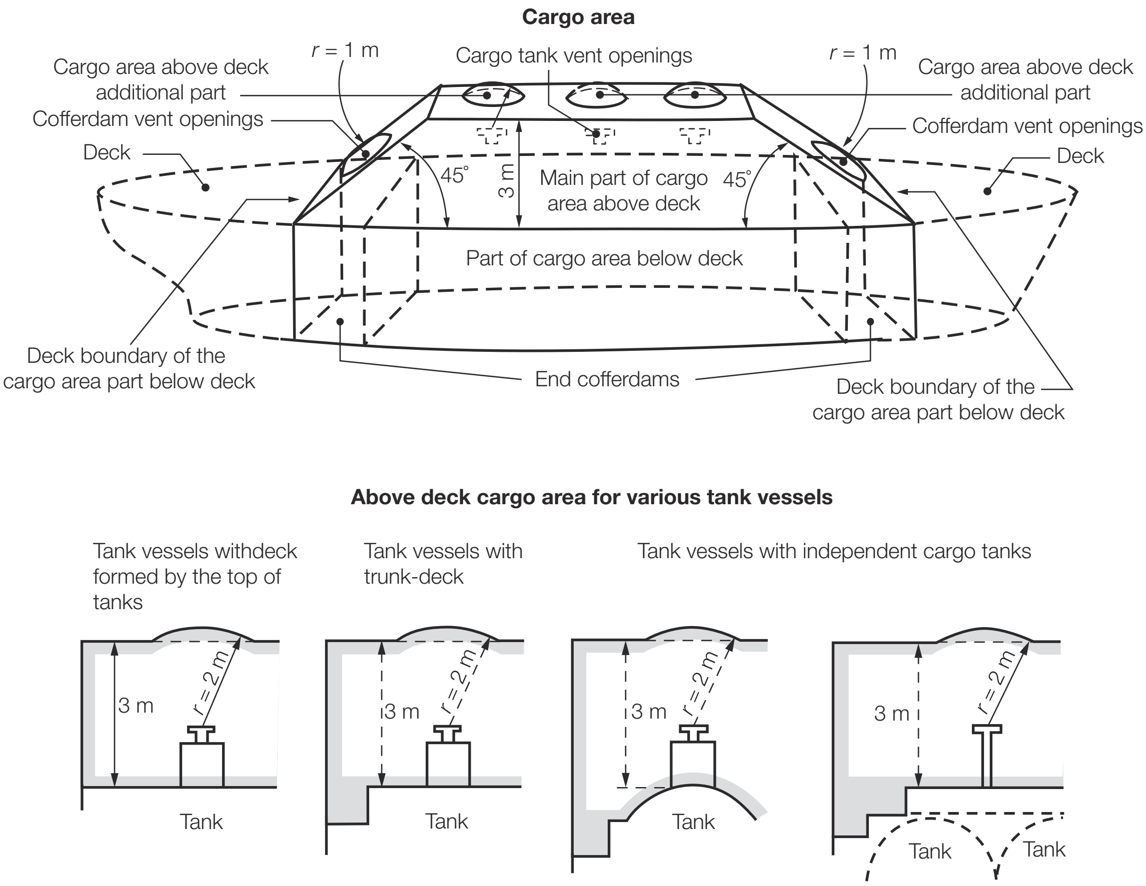


Figure 4.1.1 Above deck cargo area for various tank vessels

1.2 International Regulations

1.2.1 The requirements of Lloyd's Register's (hereinafter referred to as LR) *Rules and Regulations for the Classification of Inland Waterways Ships, July 2022* (hereinafter referred to as the Rules for Inland Waterways Ships) intended for the carriage of dangerous liquids in bulk are based on the following international regulations:

- The United Nations' ADN regulations:

  The European Agreement concerning the International Carriage of Dangerous Goods by River.

1.2.2 The exemptions and derogations to the ADN, as authorised by the UNECE (United Nations Economic Commision for Europe) - Experts on ADN, may also be taken into consideration.

1.2.3 The structural and other arrangements of tankers for the carriage of dangerous liquids in bulk, to be registered in, or to operate in countries with Regulations differing from ADN will receive appropriate special consideration if required by the relevant Authorities and/or desired by the Owner.

1.2.4 Although the contents of this Chapter take the ADN Regulations into account, the issue of an ADN Certificate on behalf of the Relevant Authorities requires full compliance with their Regulations.

1.2.5 Special attention is drawn to National and International technical and operational requirements of countries where the ship is registered or operating, which are outside classification as defined in the Rules and Regulations.

1.2.6 Electronic copies of the ADN can be downloaded from the site of the United Nations Economic Commission for Europe at

http://www.unece.org/publications/transport/dg_adn. html

1.3 Dangerous liquids

1.3.1 Dangerous liquids are those liquids which according to the recommendations of the United Nations Committee of Experts on Transport of Dangerous Goods, and according to the provisions of the ADN belong to the following classes:

- Class 2 Gases; compressed, liquefied or dissolved under pressure.
- Class 3 Flammable liquids.
- Class 6.1 Poisonous (toxic) liquids.
- Class 8 Corrosive liquids.
- Class 9 Liquids having a potential hazard during transport not described in the above categories.

1.3.2 For further details of the Classification of dangerous gases and liquids, the assigment of UN numbers, and the designation of Packing groups in relation to the Classes of liquids, reference is made to Part 2 of the ADN.

1.3.3 All dangerous goods entries are listed in Table A of Chapter 3.2 of the ADN in the numerical order of their UN Number. This table contains relevant information on the goods listed, such as name, class, packing group(s), label(s) to be affixed, packing and carriage provisions.

1.3.4 An alphabetical list of the entries mentioned in *Pt 4, Ch 4, 1.3 Dangerous liquids 1.3.3* can be found in Chapter 3.2, Table B of the ADN.

1.3.5 Only those substances entered in Table C of Part 3 of the ADN are allowed to be carried in Tankers of Type G, C or N, *see also Pt 4, Ch 4, 1.3 Dangerous liquids 1.3.6*.

1.3.6 The competent National Authority can, based on procedures by the United Nations Economic Commission for Europe, as laid down in the ADN, allow the transport of substances which have not yet been entered in Table C of Part 3 of the ADN. The resulting special permit as issued will be valid on all applicable rivers without any State or geographical limit, in compliance with the requirements as laid down in the special permit. The special permit will be valid for a maximum period of two years, which can be prolonged with a maximum period of one year after approval by the United Nations Economic Commission for Europe. For further procedures reference is made to Part 1, Section 1.5 of the ADN.

1.3.7 Attention is also drawn to the required compatibility of the cargo with the structural components of the ship, *see Pt 4, Ch 4, 1.5 Designation of dangerous liquids to ship types 1.5.3*.

1.4 Tanker types

1.4.1 For carriage of dangerous liquids of Classes 2, 3, 8 and 9, tankers are divided into the Types G, C and N.

Type G:

A Gas tanker, intended for the carriage of gases, compressed, liquefied or dissolved under pressure. The cargo tanks are to be of the closed type and to be independent from the hull structure. The ship shall comply with intact and damage stability criteria as laid down in the ADN.

Type C:

A Chemical tanker, intended for the carriage of liquids. The ship shall be of the flush-deck, double-hull type with double sides and double bottoms. The ship shall not be equipped with a trunk. The cargo tanks are to be of the closed type and may be integral with the vessel's hull structure or may consist of independent tanks installed in the hold spaces. The ship shall comply with intact and damage stability criteria as laid down in the ADN.

Type N:

A Tankship intended for the carriage of liquids. The following variations or combinations of variations can be applied in the construction of Type N tankers:

- Flush deck or trunk deck.
- Single hull or double hull.
- Integrated tanks or independent tanks.
- Closed or open tanks.
- Certain Type N ships of the double hull type should be compliant with ADN damage stability requirements.

The sketches shown in *Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N* are examples of possible hull configurations for Tankers of Types G, C and N respectively.

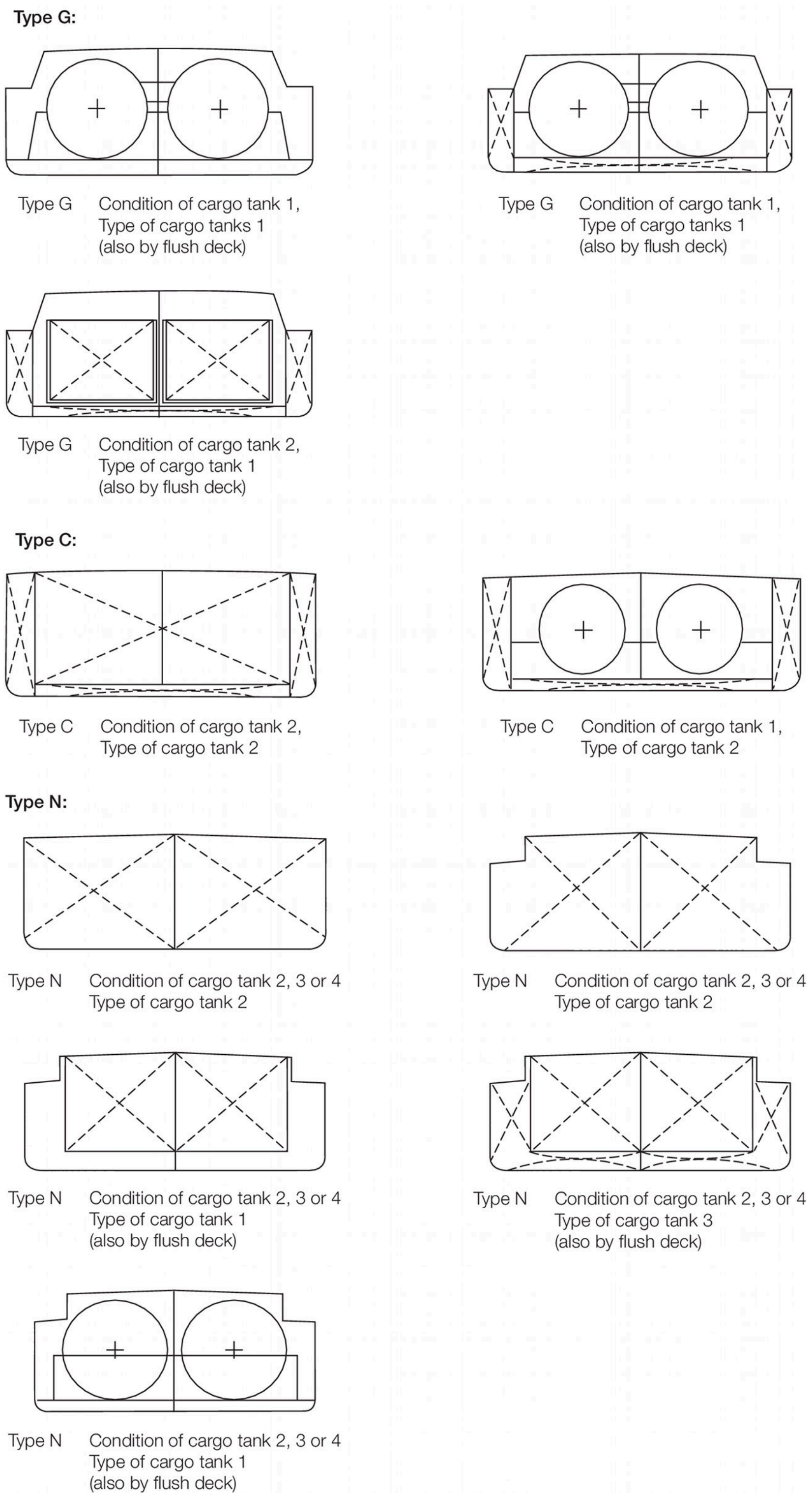


Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N

1.5 Designation of dangerous liquids to ship types

1.5.1 Dangerous liquids, carried in bulk are to be transported in tankers of the open or closed type having generally basic cross sections as in *Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N* depending on the class, classification code, packing group and properties of the liquid.

Dangerous liquids of Class 2

Gases; compressed, liquefied or dissolved under pressure are to be carried in Type G tankers.

Dangerous liquids of Class 3

Flammable liquids are generally to be carried in Type N tankers unless, depending on their properties and classification, a higher ship type is required. Liquids for which a certain ship type is requested may also be carried in a higher ship type.

Dangerous liquids of Class 6.1

Poisonous (toxic) liquids are to be carried in Chemical tankers of Type C. These liquids may also be carried in Type C or G tankers respectively.

Dangerous liquids of Class 8

Corrosive liquids are generally to be carried in Tankers of Type N, having, dependent on the properties of the liquids, open integral cargo tanks or open cargo tanks independent from the ship's structure. For some liquids, depending on their properties and classification, a higher ship type may be required. Corrosive liquids for which a certain ship type is requested may also be carried in a higher ship type.

Dangerous liquids of Class 9

Liquids having a potential hazard during transport not described in the above categories are to be carried in Tankers of Type N, having, dependent on the properties of the liquids, open integral cargo tanks or open cargo tanks independent from the ship's structure. These liquids may also be carried in tankers of Type N Closed, Type C and Type G respectively.

Non-dangerous liquids carried in bulk, are generally transported in an open type tanker having one of the basic cross-sections as for Type N tankers, *see also Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N*.

1.5.2 All additional requirements for the particular substance as contained in Table C of Part 3 of the ADN are to be complied with by the particular Tanker before a substance is allowed to be carried. This also includes any additional requirements contained in column 20 of Table C. An approved list of defined cargoes is to be carried on board.

1.5.3 In addition to the requirements of *Pt 4, Ch 4, 1.3 Dangerous liquids 1.3.5* and *Pt 4, Ch 4, 1.3 Dangerous liquids 1.3.6*, any substance is only allowed to be carried when the compatibility of the cargo with the material used in the construction of the cargo tanks of the ship has been taken into account and has been proven satisfactory.

1.5.4 After commissioning of the ship the owner is to ensure that all components used in the cargo system remain compatible with the products as mentioned in the *List of Defined Chemical Cargoes*.

1.6 Class notation

1.6.1 Ships complying with the applicable arrangements and requirements of this Chapter and of the appropriate ship type Chapter will be eligible to be classed '**A1 I.W.W.**' with further notations as indicated in the relevant ship type Chapter.

1.6.2 The Regulations for classification and assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made on the survey request form.

1.6.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 1 or 2, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.7 Stability

1.7.1 The intact or damage stability of tankers of Type G, C or N is to be in accordance with recognized international stability requirements such as laid down in the ADN. The stability calculations are to be approved by the competent National Authority. At the request of the Owner or builder and as delegated by the Competent National Authority LR can also issue a Statement of Compliance with specific national or international stability requirements.

■ *Section 2* Materials

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of *Ch 3 Rolled Steel Plates, Strip, Sections and Bars*of LR's *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and as required by the individual ship type Chapter.

2.1.2 Where steel, or coated or lined steel, used in the construction of the cargo tanks is unsuitable for the carriage of the commodity and stainless steel is required, it is generally to be of the austenitic type which is suitable for the purpose. The stainless steel is to comply with the requirements of *Ch 3, 7 Austenitic and duplex stainless steels* of the Rules for Materials. Other types of stainless steel will be specially considered.

2.1.3 Where stainless steel cargo tanks are arranged, only to preserve product purity, lower alloy stainless steels will be considered.

2.1.4 Mild steel fittings are not permitted in stainless steel cargo tanks.

2.1.5 The use of other materials will be specially considered, taking into account the properties of the commodities proposed to be carried.

2.2 Use of materials

2.2.1 The use of wood, aluminium alloys or plastic materials within the cargo area, as far as hull structural items are concerned, is prohibited, except for:

- chocking of cargo tanks which are independent of the vessel's hull and chocking of installations and equipment;
- masts and similar round timber;
- lids of boxes which are placed on the deck;
- supports and stops of any kind;
- Machinery items i.e. pumps, motors, etc.

The use of plastic materials or rubber within the cargo area is only permitted for:

- coating of cargo tanks and cargo lines;
- all kinds of gaskets (e.g. for domes or tank hatches);
- electric cables;
- hoses for loading and unloading;
- insulation of cargo tanks and cargo lines.

2.2.2 Wheelhouses may be constructed of aluminium, provided they are located abaft the aft cofferdams or forward of the forward cofferdam.

2.2.3 Means are to be provided to prevent spark formation within the cargo zone. The paint used in the cargo area shall not be liable to produce sparks in case of impact.

2.2.4 Toggles and their securing bolts (for instance, eyebolts) within the cargo zone for securing hatchcovers are not to be made of steel and are to be manufactured from either stainless steel, brass or an equivalent non-sparking material.

2.3 Protection of steelwork

2.3.1 All steelwork is to be protected according to *Pt 3, Ch 2 Materials*.

2.3.2 To avoid corrosive attack of the cargo tank structure by chemical cargoes, it is strongly recommended the structure be protected by suitable lining or coating.

2.3.3 The suitability of the lining or coating and its compatibility with the intended cargoes is the responsibility of the Builder and Owner. LR will, however, require the confirmation of the manufacturer that the lining or coating used to protect the cargo tank structure is compatible with the liquids mentioned in the *List of Defined Chemical Cargoes*.

2.3.4 Where stainless steel has been used for the construction of cargo tanks, brackish or salt water should not be carried in these tanks in order to avoid accelerated corrosion.

2.3.5 Where water ballast spaces incorporate both mild and stainless steel, special protective measures to avoid accelerated corrosion of the mild steel, such as the use of suitable coatings, are to be taken.

■ *Section 3*
Ship Arrangements

3.1 General

3.1.1 The requirements and provisions laid down in this Section are partly derived from the ADN. They form an integral part of LR's Rules for Inland Waterways Ships. Reference is made to the general terms described in *Pt 4, Ch 4, 1.1 Application and definitions*. Further ADN requirements have been included in the Rules for machinery, electrical and control Engineering and Fire Requirements as applicable.

3.2 Hold spaces, cargo tanks and service spaces

3.2.1 In accordance with ADN requirements, the maximum permissible capacity of a cargo tank shall be determined in accordance with *Table 4.3.1 Maximum permissible capacity of cargo tanks* where *Loa* x *Boa* x *D* is the product of the main dimensions of the ship, in metres, in accordance with the measurement certificate as issued by the competent National Authorities. For vessels with a trunk, *D* shall be replaced by *D*', where *D*' shall be obtained from the following formula:

$$D' = D + \left(\frac{h_t \times b_t}{Boa} \times \frac{l_t}{Loa}\right)$$

where

h_t = height of the trunk (distance between the trunk deck and main deck measured at the side of the trunk at *Loa*/2), in metres

b_t = breadth of the trunk, in metres

l_t = length of the trunk, in metres

Boa = the greatest overall breadth

Loa = the distance, in metres, from the forward side of the stem to the aftermost side of the stern

Attention is drawn to *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers* concerning the special requirements for Type C tankers.

Table 4.3.1 Maximum permissible capacity of cargo tanks

Loa x *Boa* x *D*, in m^3	Maximum permissible capacity of a cargo tank (m^3)
< 600	*Loa* x *Boa* x *H* x 0,3
600 – 3750	180 + (*Loa* x *Boa* x *D* – 600) x 0,0635
> 3750	380

3.2.2 According to *Table 4.3.1 Maximum permissible capacity of cargo tanks*, the maximum tank capacity is limited to 380 m^3 irrespective of the size of the ship. The ADN, however, offers deviations of the prescribed tank capacities, provided the crash worthiness of the vessel is suitably increased. In this case the increased collision capabilities are to be proven by additional direct and statistical calculations. These calculations should be submitted to, and be approved by, the appropriate Classification Society.

3.2.3 In case of ships not falling under the competence of the ADN the maximum permissible capacity of a cargo tank will be specially considered.

3.2.4 Independent cargo tanks are to be provided with collision chocks and arrangements to prevent floating of the tank in case of ballasting or leakage into the cargo compartment space.

3.2.5 Underdeck service spaces located in the cargo area shall be easily accessible and shall permit the safe operation of all equipment contained therein by persons wearing protective clothing and safety devices. They shall be designed so as to allow injured or unconscious personnel to be removed from such spaces without difficulties by means of fixed equipment.

3.2.6 Cofferdams, double hull spaces, double bottoms, cargo tanks, hold spaces and other accessible spaces within the cargo area shall be arranged so that they can be completely inspected and cleaned in an appropriate way. The dimensions of openings, except for those of double hull spaces and double bottoms which do not have a common boundary with the cargo tanks, shall be sufficient to allow a person wearing breathing apparatus to enter or leave the space without difficulties. These openings shall have a minimum cross-sectional area of 0,36 m^2 and a minimum width of 0,50 m. They shall be designed so as to allow injured or unconscious personnel to be removed from the bottom of the space without difficulties by means of fixed equipment. In these spaces, the free distance for passage between the reinforcements shall not be less than 0,50 m. In double bottoms, this distance may be reduced to 0,45 m.

3.2.7 Cargo tanks may have circular access openings with a diameter of not less than 0,68 m.

3.2.8 Cargo tank openings shall be located on deck in the cargo area. Cargo tank openings with a cross-section of more than 0,10 m^2 shall be located not less than 0,50 m above deck.

3.2.9 All accommodation and service spaces are to be provided with natural or mechanical ventilation of sufficient capacity.

3.2.10 Ventilation ducts of under deck service spaces located in the cargo zone shall extend down to 50 mm above the bottom of the service space. The air inlets shall be located not less than 2,00 m above the deck, at a distance not less than 2,00 m from tank openings and 6,00 m from the openings of safety valves. The extension pipes, if necessary, may be of the hinged type. For ventilation of cargo pumprooms, *see also Pt 5, Ch 13, 1.7 Cargo pump-room ventilation*.

3.2.11 Means are to be provided to prevent spark formation within the cargo zone.

3.2.12 Where a ventilation system ensuring an overpressure in accomodations wheelhouses or service spaces has been fitted and the electrical equipment in these spaces is not of the limited explosion risk type the windows are not to be capable of being opened.

3.2.13 Arrangements are to be made to contain minor spillage of the cargo.

3.2.14 Access to spaces in the cargo zone is to be direct from the upper deck.

3.2.15 Any opening in the deck in way of the cargo zone, such as for tank cleaning, sounding and taking cargo samples, is to be fitted with closing appliances which are oil and gastight at the appropriate test pressures. The number of openings is to be kept to a minimum. *See also Pt 3, Ch 11, 5 Hatchways for cargo tanks* and *Pt 3, Ch 11, 6 Hatch cover securing arrangements and tarpaulins*.

3.2.16 Fittings within cargo tanks, pump-rooms and cofferdams are to be effectively secured to the structure.

3.2.17 If below-deck cargo pump-rooms are fitted, easy access is to be provided and ladders should not be arranged vertically. Suitable handrails are to be provided.

3.2.18 Where the vessel is provided with hold spaces, the double bottoms within these spaces may be arranged as liquid fuel oil tanks, provided their depth is not less than 0,60 m.

3.2.19 For air and sounding pipes on cofferdams, see *Pt 5, Ch 13, 2.3 Air and sounding pipes*.

3.3 Protection against the ingress of gases within accommodations and entrances

3.3.1 The vessel shall be designed so as to prevent gases from penetrating into the accommodation and the service spaces. This requirement does not apply to ships of Type N Open.

3.3.2 Pumps, compressors and cargo piping shall be located in the cargo area. Cargo pumps and compressors situated on deck shall be located not less than 6,00 m from entrances to, or openings of, the accommodation and service spaces outside the cargo area. The above requirements do not apply to ships of Type N Open with the exemption of ships of Type N Open carrying corrosive liquids of Class 8.

3.3.3 The distance required by *Pt 4, Ch 4, 3.3 Protection against the ingress of gases within accommodations and entrances 3.3.2* may be reduced to 3,00 m if a transverse bulkhead complying with *Pt 4, Ch 4, 3.3 Protection against the ingress of gases within accommodations and entrances 3.3.4* is situated at the end of the cargo area. The openings shall be provided with doors.

3.3.4 The lower edges of door-openings in the sidewalls of superstructures and the coamings of access hatches to under-deck spaces shall have a height of not less than 0,50 m above the deck. This requirement need not be complied with if the wall of the superstructures facing the cargo area extends from one side of the ship to the other and has doors with sill heights of at least 0,50 m. The height of this wall shall be not less than 2,00 m. In this case, the lower edges of dooropenings in the sidewalls of superstructures and of coamings of access hatches behind this wall shall have a height of at least 0,10 m. The sills of engine-room doors and the coamings of its access hatches shall, however, always have a height not less than 0,50 m. The above requirements do not apply to ships of Type N Open.

3.3.5 In the cargo zone, the lower edge of hatches and openings in sidewalls of houses or superstructures shall have a height of at least 0,50 m above the deck. This requirement does not apply to openings of sidetanks and double bottoms and to ships of Type N Open.

3.3.6 The engine rooms shall be accessible from the deck; the entrances shall not face the cargo area. Where the doors are not located in a recess whose depth is at least equal to the door width, the hinges shall face the cargo area. This last requirement does not apply to bilge and bunkerboats.

3.3.7 Entrances of engine rooms shall be at a distance of not less than 2,00 m from the cargo area.

3.3.8 Ventilation inlets of the engine room, and when the engines do not take in air directly from the engine room, air intakes of the engines, shall be located not less than 2,00 m from the cargo area.

3.3.9 Accommodation spaces and the wheelhouse shall be located outside the cargo area forward of the fore vertical plane or abaft the aft vertical plane bounding the part of cargo area below deck. Windows of the wheelhouse which are located not less than 1,00 m above the bottom of the wheelhouse may tilt forward.

3.3.10 Entrances to spaces and openings of superstructures shall not face the cargo area. Doors opening outward and not located in a recess the depth of which is at least equal to the width of the doors shall have their hinges face the cargo area. This last requirement does not apply to bilge and bunkerboats.

3.3.11 Entrances and windows of superstructures and accommodation spaces which can be opened as well as other openings of these spaces shall be located not less than 2,00 m from the cargo area. Wheelhouse doors and windows shall not be located within 2,00 m from the cargo area, except where there is no direct connection between the wheelhouse and the accommodation. This requirement does not apply to bilge and bunkerboats.

3.3.12 Where a ventilation system ensuring an overpressure in accommodation, wheelhouses or service spaces has been fitted and the electrical equipment in these spaces is not of the limited explosion risk type, the windows are not to be capable of being opened.

3.3.13 Cofferdams shall be accessible through an access hatch having a coaming of at least 500 mm. If the cofferdam is integral with the double hull side tanks it may also be accessed through the sidetank.

3.4 Miscellaneous

3.4.1 The air pipes of all fuel oil tanks shall be led to 0,50 m above the open deck. The outlets of funnels shall be located not less than 2,00 m from the cargo area. Arrangements shall be provided to prevent the escape of sparks and the entry of water.

3.4.2 Where it is intended to carry cargoes which react hazardously with one another, they are to be separated by cofferdams, pump-rooms, void spaces, other cargo tanks or slop tanks which separate the two cargo tanks completely. In addition, there is to be corresponding segregation of the pumping and piping systems and tank vent systems.

3.5 Special requirements for Type G tankers

3.5.1 The ratio of the cargo tank length over the diameter is not to exceed seven.

3.5.2 In the cargo area, the hull shall be designed as follows:

(a) As a double-hull and double-bottom vessel. The internal distance between the sideplatings of the vessel and the longitudinal bulkheads shall not be less than 0,80 m, the height of the double bottom shall be not less than 0,60 m, the cargo tanks shall be supported by saddles extending between the tanks to not less than 20° below the horizontal centreline of the cargo tanks. Refrigerated cargo tanks shall be installed only in hold spaces bounded by double-hull spaces and double-bottom;

or

As a single hull vessel whereby the sideshell has been stiffened by stringers fitted over the full depth of the ship at a maximum spacing of 0,60 m, supported by web frames at a maximum spacing of 2,00 m. The side stringers and the web frames shall have a height of not less than 10 per cent of the depth, with a minimum of 0,30 m. The side stringers and web frames shall be fitted with flatbars made of flat steel and having a crosssection of not less that 7,5 cm^2 and 15 cm^2, respectively;

The distance between the sideplating of the vessel and the cargo tanks shall not be less than 0,80 m. The distance between the bottom of the vessel and the cargo tanks shall not be less than 0,60 m. The distance between the bottom of the vessel and the suction well shall not be less than 0,50 m.

The distance between the suction well of the cargo tanks and the bottom structure shall not be less than 0,10 m.

or

A different design of the hull in the cargo area can also be considered, provided proof can be supplied by means of direct calculations that in the event of a lateral collision with another vessel having a straight bow, an energy of 22 MJ can be absorbed without any rupture of the cargo tanks and the piping leading to the cargo tanks.

The cargo tanks shall be supported by stools extending at least to a level of 10° below the horizontal centreline of the tanks.

(b) The cargo tanks shall be fixed in such a way that they cannot float.

(c) The capacity of a suction well shall be limited to 0,10 m^3. For pressure cargo tanks, however, the capacity of a suction well may amount to 0,20 m^3.

(d) Profiles or struts connecting structural members of the sideshell with structural members on the longitudinal bulkhead are prohibited.

(e) Profiles or struts connecting structural members of the bottom shell with structural members on the inner bottom are prohibited.

3.5.3 Hold spaces shall comply with the following:

(a) The hold spaces shall be separated from the accommodation and service spaces outside the cargo area below deck by bulkheads provided with a Class A-60 fire protection insulation according to SOLAS Chapter II-2, *Regulation 3 - Definitions*. A space of not less than 0,20 m shall be provided between the cargo tanks and the end bulkheads of the hold spaces. Where the cargo tanks have plane end bulkheads, this space shall be not less than 0,50 m.

(b) The hold spaces and cargo tanks shall be capable of being inspected.

(c) All spaces in the cargo area shall be capable of being ventilated. Means for checking their gas-free condition shall be provided.

3.5.4 Service spaces below deck shall comply with the following:

(a) A space in the cargo area below deck may be arranged as a service space, provided that the bulkhead bounding the service space extends vertically to the bottom and the bulkhead not facing the cargo area extends from one side of the vessel to the other in one frame plane. This service space shall only be accessible from the deck.

(b) The service space shall be watertight with the exception of its access hatches and ventilation inlets.

3.6 Special requirements for Type C tankers

3.6.1 In the cargo area (except in way of the cofferdams) the vessel shall be designed as a flush-deck double-hull vessel, with double-hull spaces and double bottoms, but without a trunk. Cargo tanks independent of the vessel's hull as well as refrigerated cargo tanks may only be installed in a hold space which is bounded by double-hull spaces and double bottoms in accordance with *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers 3.6.5*. The cargo tanks shall not extend beyond the deck.

3.6.2 If sloptanks or tanks for residual cargo are fitted, their capacity is not to exceed 30 m^3.

3.6.3 Where independent cargo tanks are installed in the cargo space, a space of not less than 0,50 m shall be provided between such tanks and the end bulkheads of the cargo space. In this case an insulated end bulkhead meeting at least the definition for Class 'A-60' according to SOLAS 74, Chapter II-2, *Regulation 3 - Definitions*, shall be deemed equivalent to a cofferdam. For pressure cargo tanks, the distance of 0,50 m may be reduced to 0,20 m.

3.6.4 A cofferdam, the centre part of a cofferdam or another space below deck in the cargo area may be arranged as a service space, provided the bulkheads bounding the service space extend vertically to the bottom. This service space shall only be accessible from the deck. The service space shall be watertight with the exception of its access hatches and ventilation openings.

3.6.5 For double hull ships whereby the cargo tanks are integrated in the ship's structure, the distance between the side shell and the longitudinal cargo tank bulkhead shall be not less than 1,00 m. This distance may be reduced to 0,80 m, provided the following reinforcements are provided:

(a) 25 per cent increase in the thickness of the deck stringer plate;
(b) 15 per cent increase in the sideshell plating thickness;
(c) Arrangement of a longitudinal framing system at the vessel's side, where the depth of the longitudinals shall be not less than 0,15 m and the longitudinals shall have a face plate cross-sectional area of at least 7,0 cm^2.
(d) Stringers or longitudinals are to be supported by web frames spaced not more than 1,80 m apart. This distance may be increased if the longitudinals are strengthened accordingly.

When a vessel is built according to the transverse framing system, an additional stringer system shall be arranged. The distance between the stringers shall not exceed 0,80 m and their depth shall not be less than 0,15 m, provided they are completely welded to the frames. The cross-sectional area of the facebar or faceplate shall not be less than 7,0 cm^2. The mean depth of the double bottoms shall not be less than 0,70 m. At no location however, shall the depth be less than 0,60 m. The depth below the suction wells should not be less than 0,50 m.

3.6.6 Special attention is drawn to the additional ADN requirements of Part 9 Section 9.4 whereby the width of the double hull can be varied in relation to additional strengthenings and deviations from the maximum tank capacity as prescribed by the ADN. Alternative arrangements will be specially considered and should be backed-up by additional direct and statistical calculations as required by the ADN. These calculations should be submitted for approval.

3.6.7 When a vessel is built with independent or refrigerated cargo tanks, the width of the side tanks and the depth of the double bottom should not be less than 0,80 and 0,60 m respectively.

3.6.8 Profiles or struts connecting structural members of the sideshell with structural members on the longitudinal bulkhead are not allowed.

3.6.9 Profiles or struts connecting structural members of the bottom shell with structural members on the bottom of the cargo tank are not allowed.

3.6.10 When the vessel is provided with pressure cargo tanks, these tanks shall be designed for a working pressure of 400 kPa (4 bar).

3.6.11 For vessels with a length of not more than 50,00 m, the length of a cargo tank shall not exceed 10 m. For vessels with a length of more than 50,00 m, the length of a cargo tank shall not exceed 0,20L. This provision does not apply to vessels with independent built-in cylindrical tanks having a length to diameter ratio ≤ 7.

3.6.12 The capacity of a suction well shall not exceed 0,10 m^3.

3.6.13 The cargo tanks shall be separated from the accommodation, engine room and service spaces below deck outside of the cargo area, or from the ship's end in the absence of such spaces, by cofferdams of at least 0,60 m in width.

3.6.14 The test pressure for the cargo tanks and residual cargo tanks shall not be less than 1,3 times the design pressure. The test pressure for the cofferdams and open cargo tanks shall not be less than 10 kPa (0,10 bar) gauge pressure. The testing of cargo tanks and cofferdams is to be in accordance with *Pt 3, Ch 1, 7.3 Acceptance testing on completion*.

3.6.15 Where fitted, the capacity of slop tanks or residual cargo tanks is not to exceed 30 m^3. For further requirements regarding these tanks, *see Pt 5, Ch 13, 3.10 Slop tanks and vessels intended for slops for Type C tankers and Type N tankers*.

3.7 Special requirements for Type N tankers

3.7.1 On double hull ships with integrated cargo tanks or independent cargo tanks, the distance between the side shell and the cargo tank bulkhead is to be at least 0,60 m. The distance between the bottom of the ship and the cargo tank bottom is to be at least 0,50 m. This height may be reduced to 0,40 m in way of the pump suctions. The vertical distance between the pump suction of a cargo tank and the bottom structure is to be at least 0,10 m. Where a vessel is constructed with hold spaces containing cargo tanks which are independent of the structure of the vessel, the double hull space is to comply with the above. If the minimum required dimensions of openings for inspection of the cargo tank as per *Pt 4, Ch 4, 3.2 Hold spaces, cargo tanks and service spaces 3.2.6* are not feasible, it shall be possible to remove the cargo tanks easily for inspection.

3.7.2 When the vessel is provided with pressure cargo tanks, these tanks shall be designed for a working pressure of 400 kPa (4 bar).

3.7.3 For vessels with a length of not more than 50,00 m, the length of a cargo tank shall not exceed 10 m. For vessels with a length of more than 50,00 m, the length of a cargo tank shall not exceed 0,20*L*. This provision does not apply to vessels with independent built-in cylindrical tanks having a length to diameter ratio ≤ 7.

3.7.4 The cargo tanks shall be separated from the accommodation, engine room and service spaces below deck outside of the cargo area, or from the ship's end in the absence of such spaces, by cofferdams of at least 0,60 m in width.

3.7.5 Where independent cargo tanks are installed in the cargo space, a space of not less than 0,50 m shall be provided between such tanks and the end bulkheads of the cargo space. In this case an insulated end bulkhead meeting at least the definition for Class 'A-60' according to SOLAS 74, Chapter II-2, *Regulation 3 - Definitions*, shall be deemed equivalent to a cofferdam. For pressure cargo tanks, the distance of 0,50 m may be reduced to 0,20 m.

3.7.6 A cofferdam, the centre part of a cofferdam or another space below deck in the cargo area may be arranged as a service space, provided the bulkheads bounding the service space extend vertically to the bottom. This service space shall only be accessible from the deck. The service space shall be watertight with the exception of its access hatches and ventilation openings.

3.7.7 Cargo tank openings shall be fitted with gastight closures closing devices capable of withstanding the test pressure in accordance with *Pt 3, Ch 1 General*.

3.7.8 The test pressure for the cargo tanks and residual cargo tanks shall not be less than 1,3 times the design pressure. The test pressure for the cofferdams and open cargo tanks shall not be less than 10 kPa (0,10 bar) gauge pressure. The testing of cargo tanks and cofferdams is to be in accordance with *Pt 3, Ch 1, 7.3 Acceptance testing on completion*.

3.7.9 Where fitted, the capacity of slop tanks or residual cargo tanks is not to exceed 30 m^3. For further requirements regarding these tanks, see *Pt 5, Ch 13, 3.10 Slop tanks and vessels intended for slops for Type C tankers and Type N tankers*.

3.7.10 Any underdeck service space located in the cargo zone is to be provided with mechanical ventilation. The capacity is to be at least 20 air changes per hour. The ventilation exhaust ducts shall extend down to 50 mm above the bottom of the service space. The air inlets shall be located not less than 2,00 m above the deck, at a distance not less that 2,00 m from tank openings and 6,00 m from the openings of safety valves. The extension pipes, if necessary, may be of the hinged type.

3.7.11 Internal combustion engines for the vessel's propulsion as well as internal combustion engines for auxiliary machinery shall be located outside the cargo area.

■ *Section 4*
Carriage of dangerous cargoes

4.1 General

4.1.1 For general requirements, *see Pt 4, Ch 4, 1.3 Dangerous liquids* and *Pt 4, Ch 4, 1.5 Designation of dangerous liquids to ship types*. Attention is also drawn to the specific ship type requirements in *Pt 4, Ch 4, 3 Ship Arrangements*.

4.1.2 With the exception of water reactivity, reactivity with the environment is not covered within the ADN. Selfreactivity is also excluded since in that case the cargoes concerned will be required to be inerted, inhibited or stabilized as indicated in Table C of

the ADN. Interreactivity of cargoes or groups of cargoes has not been indicated in Table C of the ADN, the principal preventative arrangements being operational.

4.1.3 Where it is proposed to carry cargoes requiring temperature control for reasons of safe carriage, the temperature control arrangements are to be appropriate for the intended service and characteristics of the cargo, *see also Pt 5, Ch 13, 6 Cargo tank level gauging equipment and arrangements against overfilling* and *Pt 5, Ch 13, 7 Cargo heating arrangements*.

4.1.4 Whilst many chlorinated hydrocarbon cargoes are not appreciably corrosive to such materials as mild steel, copper and its alloys and to aluminium when they are essentially dry, certain types of those cargoes may slowly generate traces of highly corrosive hydrochloric acid when in contact with water or moist air. Operational arrangements should, therefore, be such as to minimize the probability of contamination of chlorinated hydrocarbon cargoes with water and moisture.

4.1.5 Arrangements for preserving the quality of the cargo are the responsibility of the Owners.

■ *Section 1* **General**

1.1 Application

1.1.1 This Chapter applies to propelled and non-propelled tankers (barges) of Type G, intended for the carriage of dangerous liquids of Class 2 in bulk, in association with a List of Defined Chemical Cargoes and with class notations as indicated in *Pt 4, Ch 5, 1.5 List of Defined Cargoes*. Although the ships will be primarily designed for the carriage of Class 2 liquids they could also be entitled to carry products of Classes 3, 6.1, 8 and 9 as permitted by the ADN.

1.1.2 For further information on international regulations and the significance of tanker types, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*.

1.1.3 For further information on dangerous liquids, see *Pt 4, Ch 5, 2 Cargo characteristics and requirements for carriage*.

1.1.4 This Chapter mainly provides for requirements regarding structural aspects. For basic midship configurations and particular aspects and requirements regarding the design and arrangements of Type G tankers, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*.

1.1.5 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration taking into account any relevant National Authority requirements.

1.1.6 The requirements of this Chapter take into account the European Provisions concerning the International Carriage of Dangerous Goods by Inland Waterway (ADN) which assume heavy traffic on relatively narrow waterways through heavily populated areas.

1.1.7 Ships intended to be used on waterways with conditions different from those stated in *Pt 4, Ch 5, 1.1 Application 1.1.6* and where ADN requirements are not applicable, will receive special consideration and the requirements may be modified to suit the actual conditions, *see also Pt 4, Ch 4, 1.2 International Regulations*.

1.1.8 Although the contents of this Chapter and those of *Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk* take ADN technical Regulations into account, the issue of an ADN certificate by or on behalf of the relevant Authorities, requires full compliance with their Regulations which are to be consulted in all cases.

1.1.9 Where requested to do so by the Builder or Owner, LR will investigate compliance with the ADN Regulations indicated in *Pt 4, Ch 5, 1.1 Application 1.1.8* with a view to issuing a Statement of Compliance.

1.2 Ship arrangement

1.2.1 The ship is to be so arranged that the cargo is carried in pressure tanks independent from the ship's structure.

1.2.2 Self-propelled tankers are to have the machinery aft.

1.2.3 For ADN related requirements such as the arrangement of cofferdams, double sides (as applicable), service spaces and accommodations, entrances and the protection against the ingress of gases and special requirements for Type G tankers, see *Pt 4, Ch 4, 3 Ship Arrangements*.

1.2.4 Individual cargo tanks are to be protected, as far as possible, against collision damage. The requirements are deemed to have been met if:

(a) The side shell is reinforced by side shell stringers supported by web frames over the cargo compartment length in accordance with *Pt 4, Ch 4, 3.5 Special requirements for Type G tankers* or

(b) longitudinal bulkheads are fitted at least 800 mm from the side shell over the cargo compartment length.

For details, *see Pt 4, Ch 5, 8.4 Reinforcement of single skin side shell* and *Pt 4, Ch 5, 9 Longitudinal bulkheads*.

1.2.5 The maximum tank capacity in accordance with the ADN is to be determined in accordance with *Pt 4, Ch 4, 3.2 Hold spaces, cargo tanks and service spaces*. The ADN however offers deviations of the prescribed tank capacities provided the crash worthiness of the vessel is suitably increased. This may be achieved by one, or a combination of the measures described in *Pt 4, Ch 5, 1.3 Structural configuration 1.3.5*.

1.2.6 Arrangements and scantlings forward and aft of the midship region are to comply with *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable. The remaining requirements of Part 3 are also to be complied with as appropriate for the intended arrangements.

1.2.7 The number and disposition of transverse bulkheads are to be as required by *Pt 3, Ch 7 Bulkheads*. Watertight transverse bulkheads without openings are to be fitted at the ends of the cargo compartment space.

1.3 Structural configuration

1.3.1 This Chapter provides for a basic structural configuration of a single flush deck or trunk deck hull with single or double bottom arrangement and single or double skin side construction in way of the cargo compartment space, the cross-section of the ship in way of the cargo compartment space in general being in accordance with *Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N*, for Type G ships in Chapter 4.

1.3.2 The arrangement and requirements in the following Sections are for tankers having a length not exceeding 135 m, a ratio of length to depth not exceeding 30, a ratio of breadth to depth not exceeding five and the midship region as defined in *Pt 3, Ch 3, 2.1 Definition of requirements*. When the limiting length of the ship or ratio of L/D or B/D are exceeded, the scantlings may have to be determined by direct calculation, see *Pt 3, Ch 1, 3.2 Alternative scantlings* and *Pt 3, Ch 4 Longitudinal Strength*.

1.3.3 Transverse or longitudinal framing may be adopted. For ships having a length, *L*, of not less than 50 m, it is recommended longitudinal framing be applied to deck, trunk sides and trunk deck in association with either longitudinal framing in the bottom or transverse framing in the bottom with additional efficient longitudinal stiffening integral with the tank supports. Longitudinal framing adopted for deck and/or bottom in ships with longitudinal bulkheads according to *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4.(b)* may be restricted to the areas between the longitudinal bulkheads.

1.3.4 For ADN related structural requirements regarding double and single hull structures, the arrangements of cargo tank supports and miscellaneous structural requirements, see *Pt 4, Ch 4, 3.5 Special requirements for Type G tankers*.

1.3.5 In case the ship is provided with tanks exceeding the maximum tank capacity in accordance with the ADN as described in *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.5* one, or a combination of the following measures need to be taken:

- Increase in sideshell and/or tank plating thicknesses, increase of stiffening arrangements or scantlings and spacings of primary members.
- Increase in the overall width of the double skin.
- Introduction of additional structural members.
- The appliance of special crashworthy structures.

In the above cases the increased collision capabilities are to be proven by additional direct and statistical calculations as required by the ADN. These calculations should be submitted to, and be approved by the Society.

1.4 Class notation

1.4.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2, 2 Character of classification and class notations*.

1.4.2 Ships complying with the applicable requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

‘A1 I.W.W. Tanker Type G’

or

‘A1 I.W.W. Barge Type G’

together with the appropriate design specific gravity and in association with a List of Defined Chemical Cargoes, e.g.: ‘A1 I.W.W. Tanker Type G’ p.v. +400 kPa, S.G. 1.00 in association with a List of Defined Cargoes.

1.5 List of Defined Cargoes

1.5.1 The List of Defined Cargoes for the carriage for which the ship has been approved will be attached to the Classification Certificate.

1.5.2 Only those cargoes which are included in the List of Defined Cargoes may be carried.

1.5.3 The List of Defined Cargoes will be issued by the Society and will be based on Table C of Part 3 of the ADN. Parameters will include the tanker type, cargo tank design and cargo tank type as well as the characteristics of all relevant equipment fitted in the cargo zone. All relevant parameters of Table C will be used as a basis for the list, including any relevant additional requirements contained in column 20. Attention is also drawn to *Pt 4, Ch 4, 1.5 Designation of dangerous liquids to ship types* in respect of material compatability.

1.6 Additional notations

1.6.1 Additional notations may be assigned for the following features:

(a) Tanks constructed of corrosion resistant materials, e.g. stainless steel ‘CR (s.stl)', or lined with corrosion resistant linings, e.g. rubber lining ‘CR (r.l)'.
(b) Minimum cargo temperature in °C for which the cargo tanks have been approved.
(c) Ambient design temperatures (when the carrier is suitable for continuous service in high and/or low temperature climatic conditions).

1.7 Materials

1.7.1 For materials and grades of steel, the use of materials and protection of steelwork reference is made to *Pt 4, Ch 4, 2 Materials*. The materials and grades of steel used in the construction of the cargo pressure tanks are to comply with the requirements of *Pt 5, Ch 9 Pressure Vessels other than Boilers*, taking into account the minimum temperature and maximum pressure of the cargo, also the maximum temperature if heating arrangements are fitted.

1.8 Stainless steel

1.8.1 The material is to comply with the requirements of *Ch 8, 2 Aluminium alloy rivets* and *Ch 3, 7 Austenitic and duplex stainless steels* of Lloyd’s Register’s *Rules for the Manufacture, Testing and Certification of Materials, July 2022* (hereinafter referred to as the Rules for Materials). Other types of stainless steel will be specially considered.

1.8.2 Where the specified minimum yield stress or 0,5 per cent proof stress at the operating steel temperature is less than 235 N/mm^2 (24 kgf/mm^2), scantlings will be specially considered.

1.9 Information required

1.9.1 For the information required to be submitted, see *Pt 3, Ch 1, 5 Information required*. In addition, the following are to be supplied:

(a) The design pressure of the cargo tanks.
(b) The proposed design cargo relative density (specific gravity).
(c) Details of corrosion protection of cargo tanks, ballast spaces and void spaces where applicable.

(d) Details of insulation on cargo tanks (if applicable).
(e) Details of materials of cargo tanks.
(f) Design loading sequence including data on non-uniform loading conditions that may be applicable.
(g) Particulars of filling, discharging, venting, relieving and inerting arrangements so far as applicable. Where filling, or discharging is carried out by vapour pressure, inert gas pressure or similar, the maximum pressure should be given.
(h) Details of temperature control arrangements if required or proposed to be installed.
(i) Details of tanks or spaces in the ship which will be used for carrying ballast water.
(j) The flag of the vessel and the country issuing statutory certificates.
(k) Any other relevant information that may influence the design of the ship or the proceedings during the approval process.

1.10 Symbols and definitions

1.10.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D and C_b are as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

k_L is given in *Table 2.1.1 Values of* K_L

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

s = spacing of secondary stiffeners, i.e. frames, beams, or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs etc. in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*.

■ *Section 2* Cargo characteristics and requirements for carriage

2.1 General

2.1.1 For general information on dangerous liquids and general requirements, see *Pt 4, Ch 4, 1.3 Dangerous liquids*, *Pt 4, Ch 4, 1.4 Tanker types* and *Pt 4, Ch 4, 1.5 Designation of dangerous liquids to ship types*.

2.2 Filling limits for cargo tanks

2.2.1 In service areas which are considered to have a temperate climate the maximum volume to which a cargo tank for the carriage of liquefied gases of Class 2 may be filled is not to exceed 91 per cent of the volume of the total capacity of the cargo tank.

2.2.2 When the climatic conditions in the actual service area differ considerably from those indicated in *Pt 4, Ch 4, 2.2 Use of materials 2.2.1*, the maximum volume to which the tanks may be loaded will be specially considered.

2.2.3 For Class 3, 6.1, 8 and 9 products, higher filling rates in accordance with Table C of Part 3 of the ADN are allowed.

Section 3
Cargo pressure tanks independent of the ship's structure

3.1 General

3.1.1 Cargo tanks are to be constructed as pressure vessels according to the requirements of *Pt 5, Ch 9 Pressure Vessels other than Boilers*. Proposals for non-cylindrical types of cargo tanks, complying with the requirements of *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.2* and*Pt 4, Ch 5, 1.2 Ship arrangement 1.2.3*, will receive special consideration.

3.1.2 The cargo tanks are to be placed below the continuous upper deck or trunk and are to be provided with domes, which are to be carried through the respective deck to a height of at least 0,5 m above the deck. The arrangement for the passage of the domes through the deck should allow for free movement of the tank and be such that no liquids or gas can enter into the ship.

3.1.3 Tank domes are to be arranged in about the same longitudinal position as the fixed bearer with a view to minimize relative movement between domes and deck structure.

3.1.4 Further requirements for cargo tanks and their placement in the ship are given in *Pt 4, Ch 4, 3.2 Hold spaces, cargo tanks and service spaces* and *Pt 4, Ch 4, 3.5 Special requirements for Type G tankers*.

Section 4
Longitudinal strength

4.1 Longitudinal strength requirements

4.1.1 The longitudinal strength is to comply with the requirements of *Pt 3, Ch 4 Longitudinal Strength* and for this purpose, these ships are, in general, to be considered as Category 'O' ships. The design bending moments of Category 'O' ships may be determined using the formulae in *Pt 3, Ch 4, 5 Design bending moments*.

4.1.2 Where in view of service commitments it is desired to load or discharge the ship only according to the loading/ discharge sequence 'T', the longitudinal strength may be based on the requirements for category 'T' ships.

4.1.3 The longitudinal strength may also be based on 'specified non-uniform loading conditions' in addition to the loading/ discharge sequence 'T' or 'O' as applicable, in accordance with*Pt 3, Ch 4, 2.4 Specified non-uniform loading conditions 2.4.1*.

4.1.4 The Society reserves the right to require verification by direct calculation for any of the design bending moments calculated in accordance with the above.

Section 5
Hull envelope plating

5.1 General

5.1.1 The hull envelope plating is to comply with the requirements of *Pt 4, Ch 6, 3 Hull envelope framing*.

Section 6
Single bottom structure in way of cargo compartment space

6.1 General

6.1.1 This Section covers the arrangements and requirements for transversely and longitudinally framed single bottoms in way of the cargo compartment space.

6.1.2 The scantlings are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

6.1.3 A side girder is to be fitted port and starboard between the centreline and the shell or longitudinal bulkhead near the shell and is to comply with Table 5.6.1.

Table 5.6.1 Single bottom structure in way of cargo compartment space

Item	Parameter	Requirements
Transverse framing system		
(1) Centreline girder, side girders and partial side girders	Web and face plate thickness Width of face plate	$t = (0{,}01d_w + 2{,}5)\sqrt{k}$ mm $b_f = 140s$ mm
(2) Floors	Web depth Web thickness Face plate thickness Face plate width Minimum modulus	$d_w = 40B$ mm $t_w = (0{,}01d_w + 2{,}5)\sqrt{k}$ mm $t = \geq t_w$ mm The greater of: $b_f = 16l_f$ mm $b_f = 100$ mm $Z = 7Tsl_f^{\ 2}$ cm^3
(3) Bottom structure supporting cargo tanks (combination of floors with top and bottom plating)	Minimum modulus	$Z = 8{,}5kl_f\,(W - 0{,}3l_f^{\ 2}\,T)$ cm^3
Longitudinal framing system		
(4) Centreline girder, side girders and partial side girders	Web and face plate thickness Width of face plate	$t = (0{,}01d_w + 3)\sqrt{k}$ mm $b_f = 100$ mm
(5) Transverses	Web depth at centreline Web thickness Modulus	$d_w = 40B$ mm $t = (0{,}01d_w + 3)\sqrt{k}$ mm $Z = 7kTSl_f^{\ 2}$ cm^3
(6) Bottom structure supporting cargo tanks (combination of floors/ transverses with top and bottom plating)	Minimum modulus	$Z = 8{,}5kl_f\,(W - 0{,}3l_f^2\,T)$ cm^3
(7) Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)kD_1sl_e^{\ 2}$ cm^3

Symbols		
L, B, D, T, S, s, l_e, k, Z and t are as defined in *Pt 4, Ch 5, 1.10 Symbols and definitions 1.10.1*		
d_w	=	web depth of girder or floor, in mm
l_f	=	span of floor or transverse, in metres, measured at the top of floor or transverse between side shell or between the longitudinal bulkheads according to *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4.(b)*
D_1	=	D but need not be taken greater than T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1
L_1	=	L but is to be taken not less than 40 m, nor more than 100 m
W	=	weight of tanks with maximum weight of cargo supported by the combination of floors or transverses, in tonnes

6.1.4 Where no centreline bulkhead is fitted, a centreline girder is to be arranged having the same depth as the floors or transverses in way and the scantlings are to comply with *Table 5.6.1 Single bottom structure in way of cargo compartment space*. Where the spacing between side girders required by *Pt 4, Ch 5, 6.1 General 6.1.3* does not exceed 5 m, the centreline girder may be omitted, but efficient support at the centreline is to be arranged for docking purposes.

6.1.5 For ADN related structural requirements regarding cargo tank supports, see*Pt 4, Ch 4, 3.5 Special requirements for Type G tankers*

6.2 Single bottom structure – Transversely framed ships

6.2.1 Plate floors are to be fitted at every frame and are to comply with the requirements of *Table 5.6.1 Single bottom structure in way of cargo compartment space*. Floors may be cut at the centreline, with the centre girder web plate continuous, provided the transverse strength of the floors is maintained.

6.2.2 The bottom structure supporting the cargo tanks is to comply with the requirements of *Table 5.6.1 Single bottom structure in way of cargo compartment space*.

6.2.3 For the purpose of these Rules, the structure is assumed to consist of three to five successive plate floors with a continuous top plate from side to side or between the longitudinal bulkheads according to *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4.(b)* in association with continuous side girders according to *Pt 4, Ch 5, 6.1 General 6.1.3* and at least two partial girders port and starboard, each extending over a length of six to ten frame spaces, *see Figure 5.6.1 Single bottom structure in way of cargo tank support*.

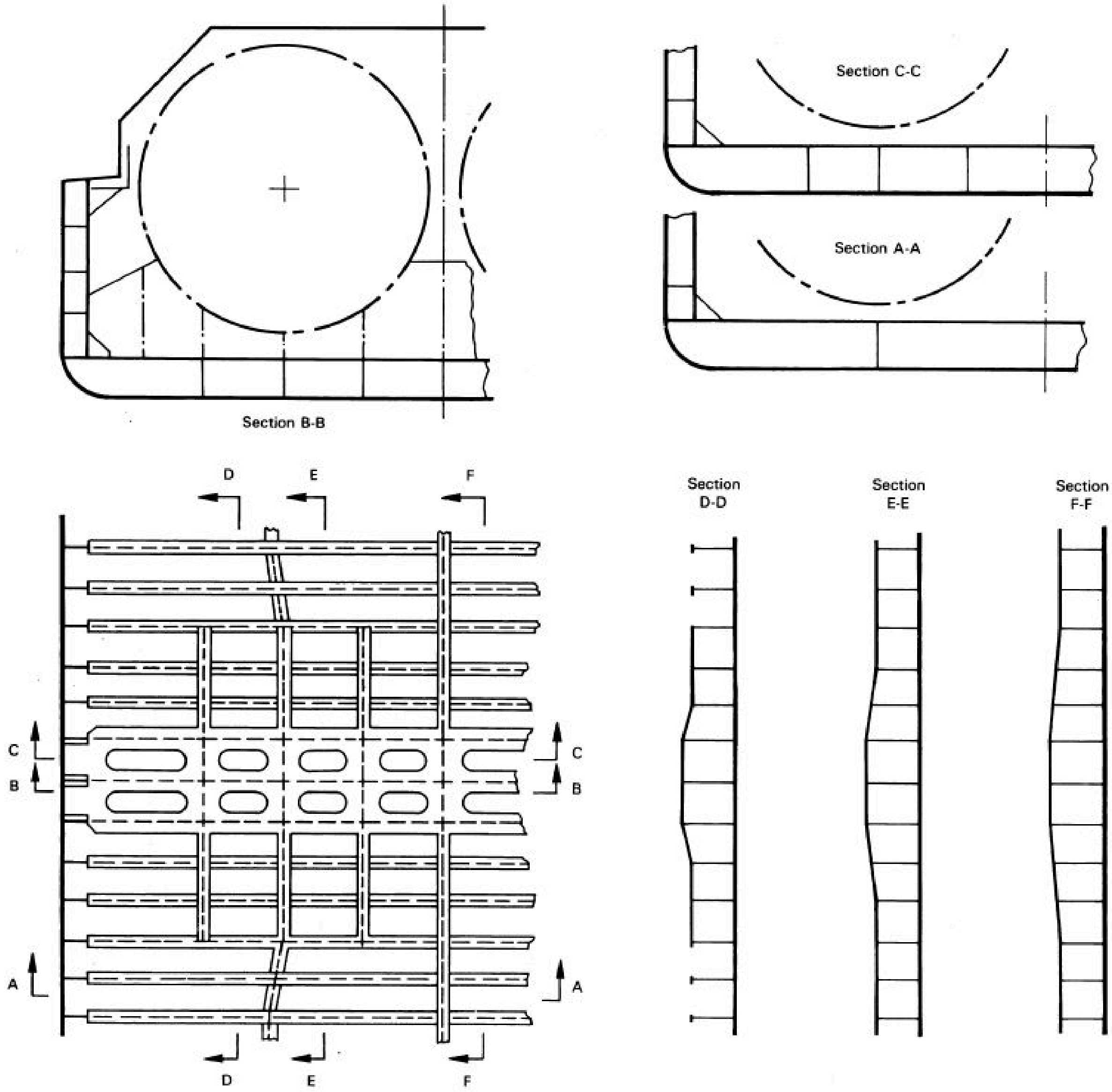


Figure 5.6.1 Single bottom structure in way of cargo tank support

6.2.4 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

6.2.5 Bottom structures with an arrangement differing from that assumed in *Pt 4, Ch 5, 6.2 Single bottom structure – Transversely framed ships 6.2.3*, will, in general, be required to be assessed by direct calculations.

6.3 Single bottom structure – Longitudinally framed ships

6.3.1 Transverses are to be fitted at a spacing not exceeding 3,5 m and are to comply with the requirements of *Table 5.6.1 Single bottom structure in way of cargo compartment space*. Vertical stiffeners having a depth of not less than 50 mm are to be fitted to the transverses at every fourth longitudinal.

6.3.2 The bottom structure supporting the cargo tanks is to comply with the requirements of *Table 5.6.1 Single bottom structure in way of cargo compartment space*.

6.3.3 For the purpose of these Rules, the structure is assumed to consist of three to five floors or transverses, having a spacing of about 0,6 m, with a continuous top plate from side to side or between the longitudinal bulkheads according to *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4.(b)*, in association with continuous side girders according to *Pt 4, Ch 5, 6.1 General 6.1.3* and at least two partial girders port and starboard, each extending forward and aft of the support structure over a full bay and in line with bottom longitudinals (*see Figure 5.6.1 Single bottom structure in way of cargo tank support*).

6.3.4 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

6.3.5 Bottom structures with an arrangement differing from that assumed in *Pt 4, Ch 5, 6.3 Single bottom structure – Longitudinally framed ships 6.3.3*, will in general be required to be assessed by direct calculation.

■ *Section 7*
Double bottom structure in way of cargo compartment space

7.1 General

7.1.1 This Section covers the arrangements and requirements for transversely and longitudinally framed double bottoms.

7.1.2 The depth of the double bottom is to be at least as required by *Table 5.7.1 Double bottom structure in way of cargo compartment space*, and is to be sufficient to ensure the the double bottom spaces are accessible for inspection, surveys, etc. *see also Pt 4, Ch 6, 3 Hull envelope framing*.

Table 5.7.1 Double bottom structure in way of cargo compartment space

Item	Parameter	Requirements
Longitudinal and transverse framing system		
(1) Centreline girder, side girders and partial side girders	Minimum depth Thickness	$d_f = 40B$ mm $t = (0{,}01d_f + 2{,}5)\sqrt{k}$ mm
(2) Inner bottom plating	Thickness	The greater of: $t = 12s$ mm $t = 6$ mm
(3) Inner bottom plating in way of tank support structure	Thickness	As bottom shell plating in way
Transverse framing system		
(4) Floors	Thickness	$t = (0{,}007d_f + 3)\sqrt{k}$ mm
(5) Watertight floors	Thickness	$t = (0{,}007d_f + 3{,}5)\sqrt{k}$ mm
(6) Combination of floors in conjunction with bottom and inner bottom plating	Modulus	$Z = 8{,}5kl_f\,(W - 0{,}45l_f^{\;2}T)$ cm^3
(7) Floors and watertight floors	Thickness	$t = (0{,}0085d_f + 3{,}5)\sqrt{k}$ mm
(8) Combination of floors in conjunction with bottom and inner bottom plating	Modulus	$Z = 8{,}5kl_f\,(W - 0{,}45l_f^{\;2}T)$ cm^3
(9) Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)\,D_1\,ksl_e^{\;2}$ cm^3
(10) Inner bottom longitudinals	Modulus	$Z = 6{,}75\left(T - \frac{d_f}{1000}\right)ksl^2_e$ cm^3

Symbols
L, *B*, *D*, *T*, *s*, l_e, *k*, *Z* and *t* are as defined in *Pt 4, Ch 5, 1.10 Symbols and definitions 1.10.1*
D = depth of girders or floors, in mm
L = span of floor, in metres, measured at the top of floor between side shell or between longitudinal bulkheads according to *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4.(b)*
D_1 = D, but need not be taken greater than T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1
L_1 = L but is to be taken not less than 40 m, nor more than 100 m
W = weight of tanks with maximum weight of cargo supported by the combination of floors, in tonnes

7.1.3 Provision is to be made for free passage of air to the ventilation pipes and where the double bottom spaces are to be used as ballast tanks, also for free passage of water to the tank suctions, account being taken of the pumping rates required. Where access openings are cut in the floors, girders or transverses, the height of the openings is not, in general, to exceed 50 per cent of the double bottom depth. Openings are to be avoided in ends of floors.

7.1.4 The depth of the double bottom in way of the support for the cargo tanks may require to be increased in height to meet the strength requirements in way.

7.1.5 For ADN related structural requirements regarding cargo tank supports, *see Pt 4, Ch 4, 3.5 Special requirements for Type G tankers*.

7.2 Girders

7.2.1 A centreline girder is generally required in ships with a breadth, B, of more than 6 m. A side girder is to be fitted on each side of the centreline in ships having a breadth, B, or more than 12 m and transversely framed bottom construction. Proposals to omit the centreline girder and/or side girders will be specially considered, but adequate support must be provided on the centreline for docking purposes.

7.3 Transversely framed double bottoms

7.3.1 Plate floors are generally to be fitted at every frame and are to comply with *Table 5.7.1 Double bottom structure in way of cargo compartment space*. Plate floors may be cut at the centreline with the centerline girder web plate continuous, provided the transverse strength of the floors is maintained.

7.3.2 As an alternative to *Pt 4, Ch 5, 7.3 Transversely framed double bottoms 7.3.1*, bracket floors may be fitted in association with plate floors spaced not more than 2,5 m apart. Scantlings and arrangements of bracket floors are to comply with the requirements for such floors in double bottoms in the forward end and aft end as indicated in *Pt 3, Ch 5, 3 Bottom structure*.

7.3.3 The bottom structure supporting the cargo tanks is to comply with the requirements of *Table 5.7.1 Double bottom structure in way of cargo compartment space*. The structure is to consist of three to five successive plate floors in conjunction with inner bottom plating of increased thickness from side to side or between the longitudinal bulkheads according to *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4.(b)* in association with continuous side girders according to *Pt 4, Ch 5, 7.2 Girders 7.2.1* and at least two partial girders port and starboard, each extending over a length of six to ten frame spaces, *see Figure 5.7.1 Double bottom structure in way of cargo tank support*. Where no continuous side girders are provided, at least three partial girders are to be fitted on each side.

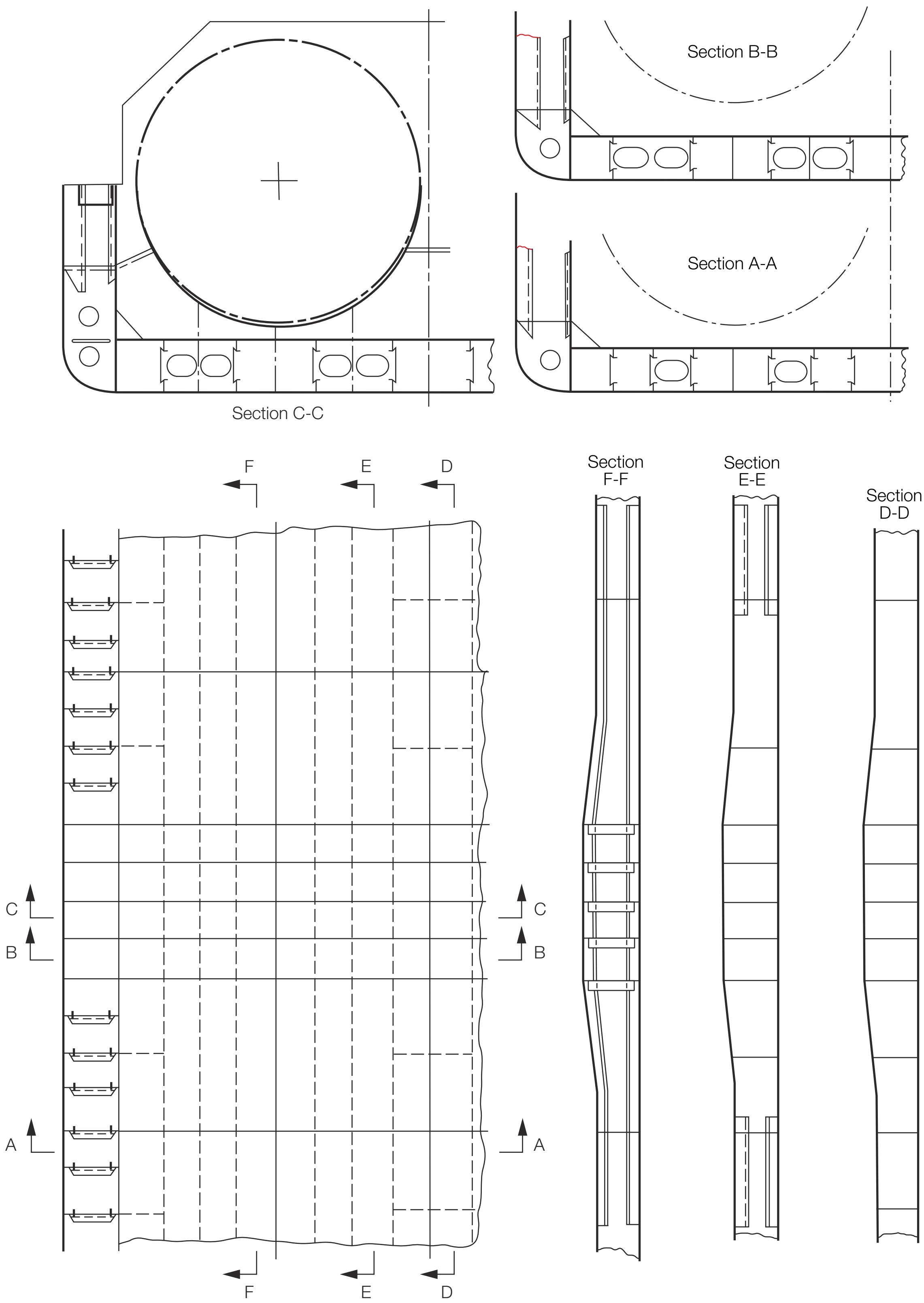


Figure 5.7.1 Double bottom structure in way of cargo tank support

7.3.4 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

7.3.5 Bottom structures with an arrangement differing from that assumed in *Pt 4, Ch 5, 7.3 Transversely framed double bottoms 7.3.3*, will, in general, be required to be assessed by direct calculation.

7.4 Longitudinally framed double bottoms

7.4.1 Plate floors are to be fitted at a spacing not exceeding 3,5 m.

7.4.2 The bottom structure supporting the cargo tanks is to comply with the requirements of *Table 5.7.1 Double bottom structure in way of cargo compartment space*. The structure is, in general, to be identical to that required by *Pt 4, Ch 5, 7.3 Transversely framed double bottoms 7.3.3*. The plate floors are to have about the same spacing as the longitudinal framing and the partial girders are to extend forward and aft of the support structure over a full bay.

7.4.3 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

7.4.4 Bottom structures with an arrangement differing from that assumed in *Pt 4, Ch 5, 7.4 Longitudinally framed double bottoms 7.4.2*, will in general be required to be assessed by direct calculation.

■ *Section 8*
Side shell framing in way of cargo compartment space

8.1 General

8.1.1 This Section covers the arrangements and requirements for side shell transverse and longitudinal framing.

8.1.2 The scantlings required are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

8.1.3 The width of a double skin, where fitted, is not to be less than 0,80 m.

8.1.4 Care is to be taken to maintain adequate transverse strength in way of the side compartments.

8.2 Transverse framing

8.2.1 The scantlings of the side framing are to comply with *Table 5.8.1 Side shell framing*.

Table 5.8.1 Side shell framing

Item	Parameter	Requirements
Transverse framing		
Side frames	Modulus	$Z = 7skl_e^2\, h_f$ cm^3
Side frames of combination		$Z = 7sl_e^2\, h_f$ cm^3
System (bottom and deck longitudinally framed and sides transversely framed)	Modulus	*See* Note
Longitudinal framing		
Side shell longitudinals	Modulus	$Z = (4{,}6 + 0{,}0342L_1)ksl_e^2\, h_f$ cm^3
Side transverses	Modulus	$Z = 10kS\, l_e^2\, h_f$ cm^3
Transversely and longitudinally framed ships		

Web frames in way of floors/transverses of bottom structure supporting the cargo tanks	Web depth Modulus	The greater of: 0,1D mm 300 mm $Z = 40kS\, l_e^{\,2}$ cm^3
Symbols		
L, D, T, S, s, l_e, k, and Z are as defined in *Pt 4, Ch 5, 1.10 Symbols and definitions 1.10.1* h_f = $h_{de} + h_t$ but not less than 2,0 m h_{de} = the vertical distance of the stiffening member under consideration to the deck at side h_t = 0 for void spaces, or 0,50 m for deeptanks but not less than the actual distance of the top of the overflow above deck L_1 = L but is to be taken not less than 40 m, nor more than 100 m W = weight of tanks with maximum weight of cargo supported by the combination of floors, in tonnes		
NOTE The section modulus of side frames in way of bottom and deck transverses is to be increased by 100 %.		

8.2.2 Web frames are to be fitted at every floor of the bottom structure supporting the cargo tanks.

8.3 Longitudinal framing

8.3.1 The scantlings of the longitudinal framing are to comply with *Table 5.8.1 Side shell framing*.

8.3.2 Side transverses are to be arranged in line with bottom and deck transverses to form a ring system for support of the side longitudinals.

8.3.3 Web frames are to be fitted at every floor of the bottom structure supporting the cargo tanks.

8.4 Reinforcement of single skin side shell

8.4.1 For ADN related structural requirements regarding minimum structural requirements for single skin sideshell structures, see *Pt 4, Ch 4, 3.5 Special requirements for Type G tankers*.

8.4.2 The depth of the web frames and stringers is to be at least twice the depth of the slot cut for longitudinal or transverse frames.

■ *Section 9*
Longitudinal bulkheads

9.1 General

9.1.1 This Section covers the requirements for compliance with *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4.(b)*.

9.2 Structural requirements

9.2.1 The construction of the longitudinal bulkheads is to comply with the requirements for vertically stiffened watertight bulkheads according to *Pt 3, Ch 7, 2 Scantlings of bulkheads*. Where the space between the longitudinal bulkheads and the side shell is designated to be used for water ballast purposes, the scantlings are to be in accordance with the requirements for deep tanks.

9.2.2 Struts are not to be used to connect longitudinal bulkhead stiffeners to the side shell structure in order to avoid possible damage to bulkheads in case of collisions.

9.2.3 Watertight transverse bulkheads are to be fitted between the shell and the longitudinal bulkheads in such a way that the ADN damage stabilty requirements are fulfilled. *See also Pt 4, Ch 4, 1.7 Stability*.

■ Section 10 Deck support structure

10.1 General

10.1.1 The deck support structure is to comply with *Table 5.10.1 Deck support structure*.

Table 5.10.1 Deck support structure

Item	Parameter	Requirements
Transverse framing		
Deck beams in flush deck ships Trunk deck beams	Modulus	$Z_b = 3{,}1\ ksl_e^{\ 2}$ cm^3
Trunk side stiffeners Deck beams abreast trunks	Modulus	$Z = Z_{\ b}$ cm^3
Deck girders	Modulus	$Z = (0{,}33 + 0{,}062L_l)\ kSl_e^2$ cm^3
Longitudinal framing		
Deck longitudinals in flush deck ships Trunk deck longitudinals Trunk side longitudinals	Modulus	$Z = (0{,}073L_l - 0{,}5)\ ksl_e^{\ 2}$ cm^3
Deck longitudinals abreast trunks	Inertia	$I = \frac{2,3}{k} l_e^{\ 2}\ Z$ cm^4
Deck transverses in flush deck ships Trunk deck transverses	Modulus	$Z_{\ t} = 3{,}1kSl_e^{\ 2}$ cm^3
Trunk side transverses Deck transverses abreast trunks	Modulus	$Z = Z_{\ t}$ cm^3
Symbols		
L, S, s, l_e, Z, k and I are as defined in *Pt 4, Ch 5, 1.10 Symbols and definitions 1.10.1* L_1 = L but is to be taken as not less than 50 m, nor more than 100 m		

Section 11
Direct calculation procedures

11.1 General

11.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship modulus.

11.1.2 Direct calculations are to be carried out as required by the Rules and may be used as an alternative to derrive scantlings instead of Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules.

11.1.3 Where direct calculation is carried out, calculation results are to be submitted together with all data in support of the calculation e.g. support conditions and details of loads.

11.2 Permissible stresses

11.2.1 In addition to the permissible stresses given in *Pt 3, Ch 4, 6 Hull bending strength* the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 5.11.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2* .

(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Pt 4, Ch 5, 11.2 Permissible stresses 11.2.1*.

Table 5.11.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2

Item	Local bending stress, σ_b, *See* Note 1	Combined bending stress, σ_c *See* Note 1	Shear stress, τ	Equivalent stress, σ_e, *See* Note 2
Bottom girders Deck girders	0,46σ_L	0,75σ_L	0,35σ_L	0,80σ_L
Bottom longitudinals Inner bottom longitudinals Deck and trunk deck longitudinals Side shell longitudinals	0,58σ_L	0,75σ_L	0,35σ_L	0,80σ_L

Where σ_L = 235/k_L

Note 1. The combined stress, σ_c, is the sum of the stresses due to longitudinal bending and local loading.

Note 2. The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Table 5.11.2 Maximum permissible stresses in local members, in N/mm^2

Item	Local bending stress, σb	Shear stress, τ	Equivalent stress, σe *See* Note 1
Non-continuous bottom girders, side stringers, *see* Note 2, deck beams, deck transverses and non-continuous deck girders	0,53σ_o	0,35σ_o	0,75σ_o
Floors, bottom transverses and bottom structure supporting tanks	0,50σ_o	0,35σ_o	0,73σ_o
Side frames	0,48σ_o	0,35σ_o	0,73σ_o
Webs supporting side stringers and side transverses, *see* Note 2	0,44σ_o	0,35σ_o	0,71σ_o

Note 1. The equivalent stress, σ_e, is to be calculated according to the formula: $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Note 2. The scantlings of stringers, or web frames fitted to comply with the requirements of *Pt 4, Ch 5, 1.2 Ship arrangement 1.2.4* are not to be determined by direct calculation but are to be in accordance with *Pt 4, Ch 5, 8.4 Reinforcement of single skin side shell*.

11.3 Structural requirements

11.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

11.3.2 In addition to the maximum permissible stresses given in *Pt 4, Ch 5, 11.2 Permissible stresses*, the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, see*Pt 3, Ch 5, 2 Hull envelope plating*.

(b) The thickness of the bilge plating amidships is to be 2 mm greater than the bottom plating, in way.

(c) The minimum thickness of the deck plating is to be not less than the thickness of deck plating at ends, see*Pt 3, Ch 5, 5.2 Deck stiffening*.

(d) Depending on the level of compressive stresses, additional buckling calculations may be required.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to propelled and nonpropelled tankers (barges) of Types C, N Closed, N Open with flame arrestors and N Open, intended for the carriage of dangerous liquid oil and chemical cargoes of Classes 3, 6.1, 8 and 9 in bulk, in association with a List of Defined Chemical Cargoes and with class notations as indicated in *Pt 4, Ch 6, 1.4 Class notation*.

1.1.2 For further information on international regulations, the significance of tanker types and further information on dangerous liquids, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*.

1.1.3 This Chapter mainly provides for requirements regarding structural aspects. For basic midship configurations and particular aspects and requirements regarding the design and arrangements of Type C and Type N tankers, *see Pt 4, Ch 4 General Requirements For Tankers Carrying Dangerous Liquids in Bulk*.

1.1.4 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration taking into account any relevant National Authority requirements.

1.1.5 The requirements of this Chapter take into account the European Provisions concerning the International Carriage of Dangerous Goods by Inland Waterway (ADN) which assume heavy traffic on relatively narrow waterways through heavily populated areas.

1.1.6 Ships intended to be used on waterways with conditions different from those stated in *Pt 4, Ch 6, 1.1 Application 1.1.4* and where ADN requirements are not applicable will receive special consideration and the requirements may be modified to suit the actual conditions, see also *Pt 4, Ch 4, 1.2 International Regulations*.

1.1.7 Although the contents of this Chapter and those of Chapter 4 take ADN technical Regulations into account, the issue of an ADN certificate by or on behalf of the relevant Authorities, requires full compliance with their Regulations which are to be consulted in all cases.

1.1.8 Where requested to do so by the Builder or Owner, Lloyd's Register (hereinafter referred to as LR) will investigate compliance with the ADN Regulations indicated in *Pt 4, Ch 6, 1.1 Application 1.1.7* with a view to issuing a Statement of Compliance.

1.2 Ship arrangement

1.2.1 Self-propelled tankers are to have the machinery aft.

1.2.2 For ADN related requirements such as the arrangement of cofferdams, double sides (as applicable), service spaces and accommodations, entrances and the protection against the ingress of gases and special requirements for Type C and N tankers, see *Pt 4, Ch 4, 3 Ship Arrangements*.

1.2.3 The maximum tank capacity in accordance with the ADN is to be determined in accordance with *Pt 4, Ch 4, 3.2 Hold spaces, cargo tanks and service spaces*. The ADN, however, offers deviations of the prescribed tank capacities, provided the crashworthiness of the vessel is suitably increased. This may be achieved by one, or a combination of the following measures described in *Pt 4, Ch 6, 1.3 Structural configuration 1.3.4*.

1.2.4 Arrangements and scantlings forward and aft of the midship region are to comply with *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable. The remaining requirements of Part 3 are also to be complied with as appropriate for the intended arrangements.

1.3 Structural configuration

1.3.1 The arrangement and requirements in the following Sections are for tankers having a length not exceeding 135 m, a ratio of length to depth not exceeding 35, a ratio of breadth to depth not exceeding 5 and the midship region as defined in *Pt 3, Ch 3, 2.1 Definition of requirements*. When the limiting length of the ship or ratio of L/D or B/D are exceeded, the scantlings may have to be determined by direct calculation, see *Pt 3, Ch 1, 3.2 Alternative scantlings* and *Pt 3, Ch 4 Longitudinal Strength*.

1.3.2 This Chapter provides for a basic structural configuration of ships having integral cargo tanks of the flush deck (Type C or Type N) or the trunk deck (Type N) type. It also provides for the structural configuration of ships having tanks independent from the ship's structure, see*Pt 4, Ch 6, 8 Construction of tankers with cargo tanks independent from the ship's structure* and *Pt 4, Ch 6, 9 Construction of cargo tanks independent from the ship's structure*.

1.3.3 The bottom, side shell and deck plating may be framed transversely or longitudinally or a combination of the two, but it is recommended that ships over 50 m in length be built according to the longitudinal framing system in bottom and deck.

1.3.4 In case the ship is provided with tanks exceeding the maximum tank capacity in accordance with the ADN as described in *Pt 4, Ch 6, 1.2 Ship arrangement 1.2.3*, one, or a combination of the following measures, need to be taken:

- Increase in sideshell and/or tank plating thicknesses, increase of stiffening arrangements or scantlings and spacings of primary members.
- Increase in the overall width of the double skin.
- Introduction of additional structural members.
- The appliance of special crashworthy structures.
- The use of alternative materials. The use of these materials is to be approved by the Society.

In the above cases, the increased collision capabilities are to be proven by additional direct and statistical calculations as required by the ADN. These calculations should be submitted to, and be approved by the Society.

1.4 Class notation

1.4.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2, 2 Character of classification and class notations*.

1.4.2 Type C Tankers complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type C'

or

'A1 I.W.W. Barge Type C'

together with the appropriate design pressure valve setting and design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Tanker Type C, p.v. +50 kPa, S.G. 1.20 in association with a List of Defined Cargoes'.

1.4.3 Type N Closed Tankers complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type N Closed'

or

'A1 I.W.W. Barge Type N Closed'

together with the appropriate design pressure valve setting and design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Tanker Type N Closed, p.v. +25 kPa, S.G. 1.00 in association with a List of Defined Cargoes'.

1.4.4 Type N Open Tankers with flame screens complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type N Open with flame screens'

or

'A1 I.W.W. Barge Type N Open with flame screens'

together with the appropriate design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Barge Type N Open with flame screens, S.G. 1.00 in association with a List of Defined Cargoes'..

1.4.5 Type N Open Tankers complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type N Open'

or

'A1 I.W.W. Barge Type N Open'

together with the appropriate design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Tanker Type N Open, S.G. 1.50 in association with a List of Defined Cargoes'.

1.4.6 Type N Tankers complying with the requirements of *Pt 4, Ch 4, 3.7 Special requirements for Type N tankers 3.7.1* and other relevant ADN requirements will be eligible to receive the additional notation 'Double Hull', e.g.: 'A1 I.W.W. Tanker Type N Closed, Double Hull, p.v. +25 kPa, S.G. 1.00 in association with a List of Defined Cargoes'.

1.4.7 Other notations, as appropriate to the arrangements, scantlings and service, may be assigned as provided for in *Pt 1, Ch 2, 2 Character of classification and class notations*.

1.5 List of Defined Cargoes

1.5.1 The List of Defined Chemical Cargoes, for the carriage of which the ship has been approved, will be attached to the Classification Certificate.

1.5.2 Only those chemical cargoes which are included in the List of Defined Chemical Cargoes may be carried.

1.5.3 The List of Defined Cargoes will be issued by the Society and will be based on Table C of Part 3 of the ADN. Parameters will include the tanker type, cargo tank design and cargo tank type as well as the characteristics of all relevant equipment fitted in the cargo zone. All relevant requirements of Table C will be used as a basis for the list, including any relevant additional requirements contained in column 20. Attention is drawn to *Pt 4, Ch 4, 1.5 Designation of dangerous liquids to ship types 1.5.3* and *Pt 4, Ch 4, 1.5 Designation of dangerous liquids to ship types 1.5.4* in respect of material compatibility.

1.6 Additional notations

1.6.1 Additional notations may be assigned for the following features:

- Tanks constructed of corrosion resistant materials, e.g. stainless steel ‘CR (s.stl)’, or lined with corrosion resistant linings, e.g. rubber lining ‘CR (r.l)’.

1.7 Heated cargoes

1.7.1 Where it is intended to carry cargoes at temperatures higher than 80°C in integrated tanks, a thermal stress calculation needs to be submitted for verification of the scantlings and arrangements.

1.8 Materials

1.8.1 For materials and grades of steel, the use of materials and protection of steelwork, reference is made to*Pt 4, Ch 4, 2 Materials*.

1.9 Stainless steel

1.9.1 The material is to comply with the requirements of *Ch 4, 2 Castings for ship and other structural applications* and *Ch 3, 7 Austenitic and duplex stainless steels* of LR’s *Rules for the Manufacture, Testing and Certification of Materials, July 2022* (hereinafter referred to as the Rules for Materials). Other types of stainless steel will be specially considered.

1.9.2 The use of clad stainless steel instead of solid stainless steel will be specially considered.

1.9.3 Where the specified minimum yield stress or 0,5 per cent proof stress at the operating steel temperature is less than 235 N/mm^2 (24 kgf/mm^2), scantlings will have to be increased and will be specially considered.

1.10 Compartment minimum thickness

1.10.1 Within the cargo tank region, including cofferdams and under deck pump-rooms, the thickness of all plating and structural members is to be not less than:

t = 0,025(135 + L) mm

L is the Rule length of the ship, in metres, which is to be taken as not less than 65 m.

1.10.2 For stainless steel structures, the thickness obtained with 1.10.1 may be reduced by 0,5 mm.

1.11 Information required

1.11.1 For the information required to be submitted, see *Pt 3, Ch 1, 5 Information required*. In addition, the following are to be supplied:

(a) The desired tanker type notation and the cargo tank type.
(b) The opening pressure of the high velocity vent valves.
(c) The proposed design cargo relative density (specific gravity).
(d) Maximum cargo temperature in °C when loaded or carried.
(e) Details of corrosion protection of cargo tanks, ballast spaces and void spaces if applied.
(f) Details of materials to be used in the construction of the cargo tanks if not made of mild steel.
(g) Loading sequence desired and data on any other nonuniform loading conditions that may be applicable.
(h) The flag of the vessel and the country issuing statutory certificates.
(i) Any other relevant information that may influence the design of the ship or the proceedings during the approval process.

1.12 Symbols and definitions

1.12.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T are as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

k_L is given in *Table 2.1.1 Values of K_L*

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

h_d = cargo tank design pressure head

= for Type N Open tankers and for Type N Open tankers with flame screens: 0,6 m

= for Type N Closed and Type C tankers: The design pressure head as required by the specifications for the ship but not less than 1,02 m (10 kPa design pressure) and not greater than 5,10 m (50 kPa design pressure)

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

s = spacing of secondary stiffeners, i.e. frames, beams, or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs, etc. in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

ρ = relative density (specific gravity), but is to be taken as not less than 1 tonne/m^3.

■ *Section 2* Longitudinal strength

2.1 Longitudinal strength requirements

2.1.1 The longitudinal strength is to comply with the requirements of *Pt 3, Ch 4 Longitudinal Strength*. and for this purpose, these ships are, in general, to be considered as Category 'T' ships. For this purpose, the design bending moments of Category 'T' ships may be determined using the formulae in *Pt 3, Ch 4, 5 Design bending moments*.

2.1.2 If the ship is to be loaded or discharged, according to the loading/discharge sequence 'O' or equivalent in view of service commitments, the longitudinal strength is to be based on the requirements for Category 'O' ships.

2.1.3 The longitudinal strength may be based on a defined loading/discharge sequence 'D' in accordance with *Pt 3, Ch 4, 2.3 Longitudinal strength categories 2.3.1*.

2.1.4 The longitudinal strength may also be based on 'Specified non-uniform loading conditions' in addition to the loading/discharge sequence 'T' or 'O' as applicable, in accordance with *Pt 3, Ch 4, 2.4 Specified non-uniform loading conditions 2.4.1*.

2.1.5 The Society reserves the right to require verification by direct calculation for any of the design bending moments calculated in accordance with the above.

■ *Section 3* Hull envelope framing

3.1 General

3.1.1 This Section covers the arrangements and requirements for the hull envelope plating for flush and trunk deck tankers *viz*: keel, bottom, bilge, side shell plating, sheerstrake, deck, trunk side and trunk deck plating so far as applicable. Tankers of Type C are to be of the flush deck type, *see also Pt 4, Ch 4, 3.6 Special requirements for Type C tankers*.

3.1.2 The thickness of the hull envelope plating amidships is to be not less than required in this Section, but in ships over 65 m in length, the thickness of bottom plating and top side plating (and/or longitudinal stiffening members) may require to be increased to obtain the midship section modulus as required in *Pt 3, Ch 4 Longitudinal Strength*.

3.1.3 The midship thicknesses are to be maintained over 0,5*L* amidships, except where stated otherwise in this Section and may be tapered to the end thicknesses in the fore and aft ends of the ship, *see Pt 3, Ch 5 Fore End and Aft End Structure*, according to the requirements for taper given in*Pt 3, Ch 3, 2.5 Principles for taper*.

3.1.4 Openings in the shell plating are to have well rounded corners; compensation is, generally, only required for openings having a width greater than 250 mm. Openings in way of, or near to the bilge radius are to be circular or elliptical.

3.1.5 Where openings are made in the deck plating for access to tanks, the deck plating in way is, generally, to be increased in thickness to compensate for the material cut out. Where a deck longitudinal is cut in way of an opening, compensation is to be arranged to ensure full continuity of sectional area. However, no compensation need be fitted if the loss of sectional area has already been taken into consideration in calculating the actual midship hull section modulus.

3.1.6 Circular openings in the deck of a diameter of 150 mm or less need not be compensated, provided they are situated well clear of other openings and the area cut out transversely over the deck does not exceed three per cent of the total area.

3.1.7 Plate panels, in which openings are cut are, where necessary, to be adequately stiffened against compression.

3.2 Keel

3.2.1 The breadth and thickness of the keel is to comply with the requirements of *Table 6.3.1 Hull envelope plating and inner bottom plating - All tankers* and is to be maintained over the full length of the ship.

Table 6.3.1 Hull envelope plating and inner bottom plating - All tankers

Item and Parameter		Required minimum scantlings, *see* Note 1	
(1)	Plate keel	0,1*B* m, but not less than 0,75 m	
	Breadth	As bottom plating, t_b	
	Thickness	When there is a rise of floor, the thickness is to be increased by 1 mm	
(2)	Bottom plating	Longitudinal framing	Transverse framing
	Thickness	The greater of:	The greater of:
	See note 2	$t_b = (5,6 + 0,054L)\sqrt{ks}$ mm	$t_b = (5,6 + 0,054L)\sqrt{ks}$ mm
		$t_b = 10s$ mm	$t_b = 10s$ mm
(3)	Bilge Plating	Longitudinal and transverse framing	
	Thickness	$t_b = t_b + 2$ mm	
(4)	Bilge chine bars		
	(a)	Round bars	
		Diameter	$3t_b$ mm, but not less than 30 mm
	(b)	Square bars	
		Width	$3t_b$ mm, but not less than 30 mm
	(c)	Angle bars	
		Flange thickness	$t_b = 2t_b$ mm
(5)	Side shell plating	The greater of:	
	Thickness	$t_b = (5,6 + 0,054L)\sqrt{s}$ *mm*	
	See Note 2	$t_b = 10s$ *mm*	
(6)	Sheerstrake		
	Width	0,08*D* mm but not less than 0,2 m	
	Thickness	$t = t_s + 5$ mm, *see* Note 3	

(7)	Doublers clear of sheerstrake (when fitted)	
	Width	W_d= between 0,10 and 0,45 m
	Thickness	The greater of: $t = 30W_d$ $t = t_s$
(8)	Inner bottom plating	The greater of: t = 12s mm $t = 4s\sqrt{kh_s} + K_c$ mm
Symbols		
L, B, D, T, S, s, k and t are as defined in *Pt 4, Ch 6, 1.12 Symbols and definitions 1.12.1* h_g = as defined in *Table 6.4.1 Hull framing - Transversely framed ships* K_c = plate thickness factor = 1,5 for mild steel For stainless steel, *see Pt 3, Ch 4, 7.3 Corrosion additions 7.3.7* t_b = thickness of bottom plating, in mm t_s = required minimum thickness for the sideshell plating calculated at the same location, in mm D_1 = depth D for flush deck tankers and depth to trunk deck for trunk deck tankers		
Note 1. The minimum compartment thickness of the tank structure is not to be less than as required by *Pt 4, Ch 6, 1.10 Compartment minimum thickness*. Note 2. For single skin tankers intended for the carriage of cargoes having relative densities (specific gravities) in excess of 1,0 and for single skin tankers with design vapour pressures in excess of 10 kPa, the thickness is also to comply with the requirements for tank boundary plating, in accordance with Section 7, whereby a minimum draught of 0,4T may be assumed to represent the counter-effect of outside water pressure. Note 3. For ships up to a length, L, of 65 m, where a substantial welded steel rubbing bar is fitted, the sheerstrake may be of the same thickness as the side shell in way.		

3.3 Shell plating

3.3.1 The thickness of the bottom plating and side shell plating is to comply with the requirements of *Table 6.3.1 Hull envelope plating and inner bottom plating - All tankers*.

3.3.2 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the sideshell plating is to be increased, *see Pt 4, Ch 6, 3.11 Double skin arrangement 3.11.2*.

3.4 Bilge plating

3.4.1 The thickness of the bilge plating amidships is to comply with the requirements of *Table 6.3.1 Hull envelope plating and inner bottom plating - All tankers*, and is to be maintained from well beyond the forward shoulder to well beyond the aft shoulder of the bilge, but at least over the midship region. For definition of shoulders, *see Pt 3, Ch 5, 2.4 Shell plating*.

3.4.2 The bilge radius is to be at least 10 times the thickness of the bilge plating and is to extend at least 100 mm on either side of the radius of the bilge plate.

3.4.3 Square bilges, constructed by solid round, square, or externally fitted angle bars, *see Figure 6.3.1 Square bilge arrangements*, are to comply with *Table 6.3.1 Hull envelope plating and inner bottom plating - All tankers*. The bottom plating and the side shell plating, adjacent to the round, square or angle bars, need not be increased in thickness above that of the bottom plating or side shell plating in way.

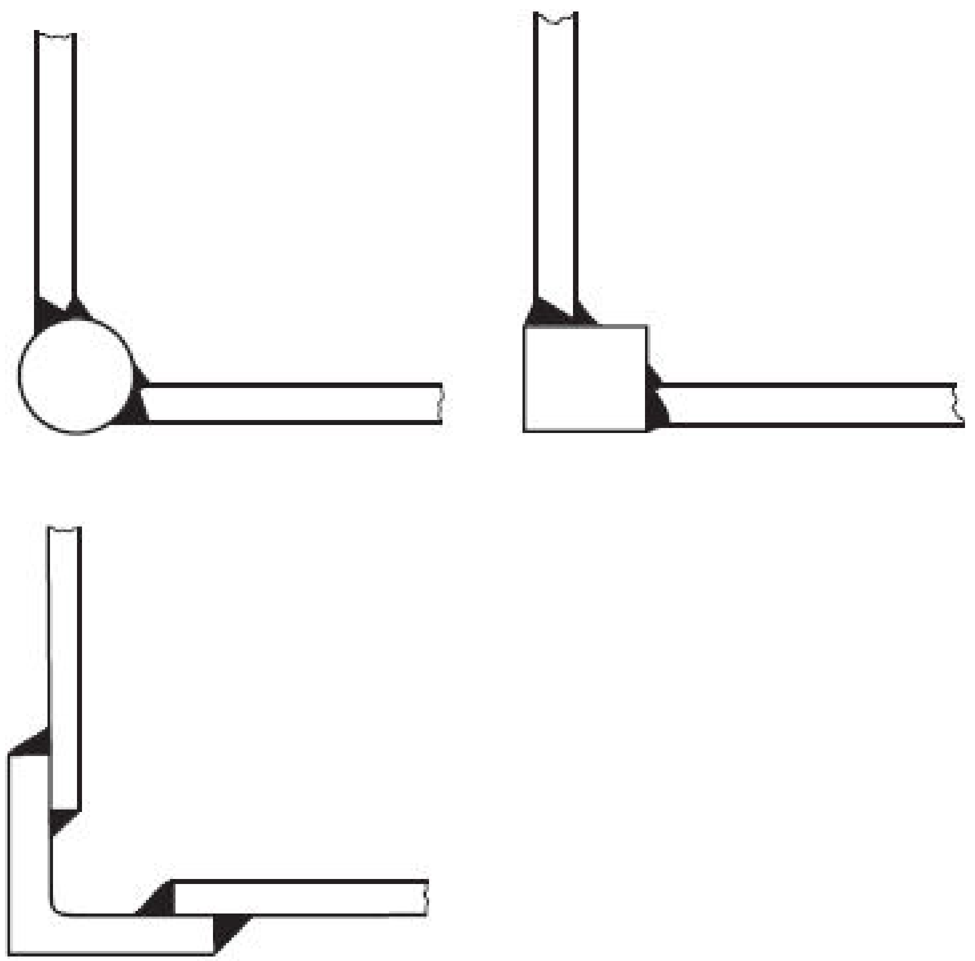


Figure 6.3.1 Square bilge arrangements

3.5 Sheerstrake

3.5.1 The width and the thickness of the sheerstrake is to comply with the requirements of *Table 6.3.1 Hull envelope plating and inner bottom plating - All tankers*.

3.5.2 In case of a rounded gunwale or when the sheerstrake is of the 'tumble home' type, a strake of increased thickness is to be fitted as high as possible, covering the area where the ship has its maximum width. The thickness and extent are to comply with *Pt 4, Ch 6, 3.5 Sheerstrake 3.5.1*.

3.5.3 In case of a rounded gunwale the radius of the curvature of the strake is not to be less than 10 times the actual plating thickness.

3.5.4 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the sheerstrake plating is to be increased, see *Pt 4, Ch 6, 3.11 Double skin arrangement 3.11.2*.

3.6 Deck plating of transversely framed flush deck tankers

3.6.1 The thickness of the deck plating is to comply with the requirements of *Table 6.3.2 Hull envelope plating - Flush deck tankers deck plating*.

Table 6.3.2 Hull envelope plating - Flush deck tankers deck plating

Item and parameter	Longitudinal framing	Transverse framing
Deck plating: Thickness *See* Note	The greater of: $t = (5,6 + 0,039L)\sqrt{ks}$ mm $t = 10s$ mm	The greater of: $t = (5,6 + 0,039L)\sqrt{ks}$ mm $t = 10s$ mm
Symbols		
L, *B*, *D*, *S*, *s*, *k* and *t* are as defined in *Pt 4, Ch 6, 1.12 Symbols and definitions 1.12.1*		
NOTE The minimum compartment thickness of the tank structure is not to be less than as required by *Pt 4, Ch 6, 1.10 Compartment minimum thickness*.		

3.6.2 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the deck plating is to be increased, *see Pt 4, Ch 6, 3.11 Double skin arrangement 3.11.2*.

3.7 Trunk deck plating, trunk side plating and plating of deck abreast trunk of transversely framed trunk deck tankers

3.7.1 The thickness of plating of the trunk deck, trunk side and deck abreast of the trunk is to comply with the requirements of *Table 6.3.3 Hull envelope plating - Trunk deck tankers trunk plating and deck plating*.

Table 6.3.3 Hull envelope plating - Trunk deck tankers trunk plating and deck plating

Item and parameter	Longitudinal framing	Transverse framing
(1) Trunk deck plating Thickness *See* Note	The greater of: $t_{trd} = (5,6 + 0,039L)\sqrt{ks_t}$ mm $t_{trd} = 10s_t$ mm	The greater of: $t_{trd} = (5,6 + 0,039L)\sqrt{ks}$ mm $t_{trd} = 10s_t$ mm
(2) Trunk side plating Thickness, *see* Note	The greater of: $t = t_{trd}$ mm $t = t_{trd}\sqrt{\frac{S_{ts}}{S_t}}$ mm	The greater of: $t = t_{trd}$ mm
(3) Deck plating abreast trunk Thickness, *see* Note	The greater of: $t = 0,9t_{trd}\sqrt{\frac{S_d}{S_t}}$ mm $t = (5,6 + 0,039L)\sqrt{s_t}$ mm $t = 10s_d$ mm	The greater of: $t = t_{trd}$ mm $t = (5,6 + 0,039L)\sqrt{s_t}$ mm $t = 10s$ mm
Symbols		

L, *s* and *t* as defined in *Pt 4, Ch 6, 1.12 Symbols and definitions 1.12.1* s = spacing of transverse deck beams, in metres s_{d} = spacing of longitudinals of deck abreast trunk or breadth of deck if no longitudinals are fitted, in metres, see *Figure 6.3.2 Cross-section of longitudinally framed trunk deck tanker* s_{t} = spacing of trunk deck longitudinals, in metres s_{ts} = spacing of trunk side longitudinals or height of trunk if no longitudinals are fitted, in metres, see *Figure 6.3.2 Cross-section of longitudinally framed trunk deck tanker*, s_{ts} is to be taken as not less than s_{t} t_{trd} = thickness of trunk deck plating, in mm B_{trd} = breadth of trunk deck, in metres D_{trd} = depth of ship to trunk deck, measured at the middle of the length *L* from top of keel to top of the deck beam of the trunk deck at side of trunk, in metres
NOTE The minimum thickness of the tank structure is not to be less than as required by *Pt 4, Ch 6, 1.10 Compartment minimum thickness*

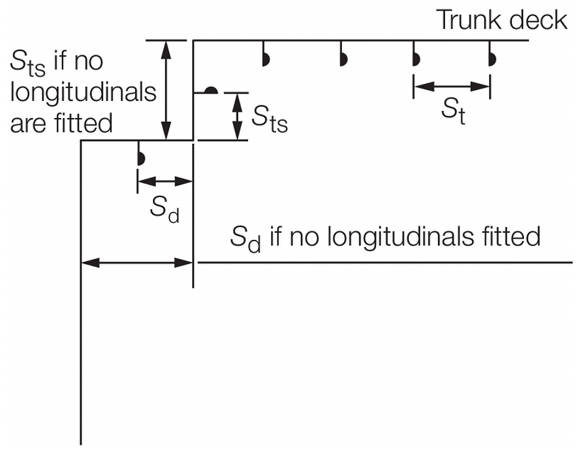


Figure 6.3.2 Cross-section of longitudinally framed trunk deck tanker

3.8 Deck plating of longitudinally framed flush deck tankers

3.8.1 The thickness of the deck plating is to comply with the requirements of *Table 6.3.2 Hull envelope plating - Flush deck tankers deck plating*.

3.8.2 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the deck plating is to be increased, *see Pt 4, Ch 6, 3.11 Double skin arrangement 3.11.2*.

3.9 Trunk deck plating, trunk side plating and plating of deck abreast trunk of longitudinally framed trunk deck tankers

3.9.1 The thickness of plating of the trunk deck, trunk side and the deck abreast of the trunk is to comply with the requirements of *Table 6.3.3 Hull envelope plating - Trunk deck tankers trunk plating and deck plating*.

3.10 Inner bottom plating

3.10.1 The thickness of the inner bottom plating is to comply with the requirements of *Table 6.3.1 Hull envelope plating and inner bottom plating - All tankers*.

3.11 Double skin arrangement

3.11.1 Where a double skin is fitted and the inner skin forms the boundary of cargo tanks, the plating of the inner skin is to comply with the requirements of *Pt 4, Ch 6, 7 Longitudinal and transverse bulkheads of integral cargo tanks* for tank bulkhead plating. Otherwise the plating of the inner skin is to comply with the requirements for deep tank or watertight bulkheads, as applicable, *see Pt 3, Ch 7 Bulkheads*.

3.11.2 For details regarding the accessibility and the standard required width of the double skin on Type C tankers, reference is made to *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers*. Requirements are also given for strengthening the double skin in cases where the width is reduced to the minimum value as allowed by the ADN. In this case, the required percentages of increase in thicknesses of the deck, sideshell and sheerstrake plating as given in *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers* are to be applied to the minimum values as calculated by using this Chapter.

3.11.3 For details regarding the accessibility and the standard required width of the double skin on Type N tankers reference is made to *Pt 4, Ch 4, 3.7 Special requirements for Type N tankers*.

■ *Section 4*
Hull envelope framing – Transversely framed ships

4.1 General

4.1.1 This Section covers the arrangements and requirements for the transverse hull framing of the midship region of flush deck and trunk deck tankers. The scantlings of floors, bottom girders, frames, stringers and web frames, deck beams, deck girders and pillars are to be in accordance with *Table 6.4.1 Hull framing - Transversely framed ships*.

Table 6.4.1 Hull framing - Transversely framed ships

Item	Parameter	Requirement
Floors	Modulus	$Z = 6{,}6ksl_f^2h_b$ cm^3
		$d_f \geq 30B$ mm
	Web thickness	$t = (0{,}01d_f + 2)\sqrt{k}$ mm
Centre girder	Web depth	$d = d_f$ mm
	Web and face plate thickness	$t = (0{,}01d_f + 2)\sqrt{k}$ mm
	Face plate width	$w = 140s$ mm
Side girders	Scantlings	As centre girder
Side frames in cargo tanks (single skin)	Modulus	$Z = 7ksl_e^2h_g$ cm^3
Side frames in double skin	Modulus	$Z = 6{,}6ksl_e^2h_f$ cm^3
Deck beams	Modulus	$Z = 6{,}6ksl_e^2h_g$ cm^3
Deck girders	Modulus	$Z = (0{,}7 + 0{,}132L_1)\,ksl_e^2h_g$ cm^3
		See Note 1
Deck beams on trunk deck	Modulus	$Z_{tdb} = 6{,}6ksl_e^2h_g$ cm^3
Trunk side stiffeners and deck beams abreast trunk	Modulus	$Z = Z_{tdb}$ cm^3

Pillars	Cross-sectional area	A = 4,5 + 0,9P cm^2
Stringers in cargo tanks (single skin)	Modulus	Z = 6,6$kl_s^2Sh_g$ cm^3
Stringers in double skin	Modulus	Z = 6,6$kl_s^2Sh_f$ cm^3
Webs, supporting stringers and girders	Modulus	Z to be determined from calculations using a stress of 103,0 N/mm^2 (10,5 kgf/mm^2) assuming fixed ends, in association with the head, h_g
Plate webs in double skin	Thickness	The greater of: t = 7 mm t = 9s_d
Symbols		

L, B, D, T, S, s, l_e, h_d, Z, l, ρ, k and t as defined in *Pt 4, Ch 6, 1.12 Symbols and definitions 1.12.1*

d_f = depth of floor, in mm

h = the vertical distance from the middle of the effective length of the stiffening member under consideration to the top of the tank, excluding hatchways, in metres

h_b = the greater of:

(a) the depth, D, but need not to be taken greater than T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1

(b) $h_g - 0{,}4T$ m

h_f = $h_{de} + h_s$, but not less than 2 m

h_{de} = the vertical distance at mid-span of the stiffening member under consideration to the deck at side

h_s = 0 for void spaces or 0,5 m for deeptanks but not less than the actual distance of the top of the overflow above deck

h_g = $h\rho + h_d + 0{,}2$ m

h_t = test head as defined in *Table 1.7.2 Testing requirements* in Pt 3, Ch 1, in metres

l_e = span of floor being 0,5B in ships with a centreline bulkhead and in ships with two longitudinal bulkheads the spacing of the bulkheads or 0,4B, whichever is the greater, in metres

l_s = span of stringer, in metres

D_2 = D, but need not be taken greater than T + 0,4 m for Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1

K = 1 for Category ‘O’ ships

K = 0,75 for Category ‘T’ ships

L_1 = L, but is to be not less than 50 m, nor more than 100 m

P = load supported by the pillar, in tonne-f

s_d = stiffener spacing or width of double skin whichever is the smaller

Z_b = section modulus of trunk deck transverses, in cm^3

Z_{tdb} = section modulus of trunk deck beams, in cm^3

Note 1. In case the scantlings of longitudinal members result in an appreciable excess in the hull midship section modulus as required by *Pt 3, Ch 4 Longitudinal Strength*, for the ship type concerned, a reduction in the modulus of the relevant members may be applied, provided the permissible combined bending stress and the permissible local bending stress are not exceeded. For permissible stresses, see *Pt 4, Ch 6, 12 Direct calculation procedures*.

Note 2. The minimum compartment thickness of the tank structure is not to be less than as required by *Pt 4, Ch 6, 1.10 Compartment minimum thickness*.

4.1.2 Scantlings given in *Table 6.4.1 Hull framing - Transversely framed ships* are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted,

the modulus of stiffening member is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

4.1.3 Outside the midship region the structure is to be scarfed into the fore end and aft end structure as provided for in *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable.

4.1.4 It is recommended that the bottom of ships regularly resting aground be additionally strengthened to withstand the stresses to which it may be subjected. In such ships scallops or openings (unless reinforced) are not to be made in the lower region of the bottom framing.

4.2 Floors

4.2.1 Plate floors are to be fitted at every frame. The upper edge of the floors is to be suitably stiffened whilst adequate anti-tripping arrangements are to be provided.

4.2.2 The floors are to be provided with sufficient openings to obtain a good flow of cargo to the suction pipes in the tank. In way of large openings additional stiffening may be required. If floors are of scalloped construction, scallops are not to be made in way of the bilge, near longitudinal bulkheads, centre or side girders, or in way of pillars.

4.3 Centreline girder

4.3.1 When the spacing between longitudinal bulkheads in ships without a centreline bulkhead exceeds 5 m, a centreline girder is to be fitted. When the spacing between the longitudinal bulkheads is 5 m or less, an intercostal docking bar is to be fitted at the centreline.

4.4 Side girder

4.4.1 In ships with a centreline bulkhead only and a breadth, *B*, exceeding 12 m, a side girder is to be fitted port and starboard at about $\frac{1}{4}$ *B* from the centreline bulkhead. In ships with two longitudinal bulkheads, where the spacing between the centreline of the girder and the longitudinal bulkheads exceeds 6 m, a side girder is to be fitted port and starboard.

4.5 Side frames, stringers and web frames

4.5.1 Side frames are to be fitted at every frame and are to be connected top and bottom, *see Pt 4, Ch 6, 4.1 General 4.1.2*.

4.5.2 Stringers may be taken into account into the calculation of the frames provided the stringers are fully effective and properly connected to the supporting webframes.

4.6 Deck support – Flush deck tankers

4.6.1 Deck beams are to be fitted at every frame and are to be connected at their ends, *see Pt 4, Ch 6, 4.1 General 4.1.2*.

4.6.2 A deck beam which is cut in way of an opening in the deck, is to be connected to efficient carlings.

4.6.3 For support of deck beams, deck girders may be fitted in conjunction with widely spaced pillars or web beams.

4.6.4 Tubular pillars or other hollow pillars are not to be used. The pillars are to be bracketed top and bottom. The sizes of brackets and welding are to take account of the maximum tensile force in the pillar when the tank is under internal pressure. The floor in way of the pillar heel is to be connected to the adjacent floors by an intercostal girder if not already in line with a Rule side girder.

4.7 Deck support – Trunk deck tankers

4.7.1 Trunk deck beams, trunk side stiffeners and deck beams are to be fitted at every frame and are to be connected at their ends, *see Pt 4, Ch 6, 4.1 General 4.1.2*.

4.7.2 Where beams are cut in way of openings, the requirements of *Pt 4, Ch 6, 4.6 Deck support – Flush deck tankers 4.6.2* are to be complied with.

4.7.3 Arrangements for support of deck beams are to comply with the requirements of *Pt 4, Ch 6, 4.6 Deck support – Flush deck tankers 4.6.3* and *Pt 4, Ch 6, 4.6 Deck support – Flush deck tankers 4.6.4*.

4.8 Double skin arrangement

4.8.1 The scantlings of the structure in the double skin are to be in accordance with *Table 6.4.1 Hull framing - Transversely framed ships*.

4.8.2 Where the inner skin forms the boundary of cargo tanks, the scantlings of stiffening members are to comply with the requirements of *Pt 4, Ch 6, 7 Longitudinal and transverse bulkheads of integral cargo tanks*. Otherwise, the scantlings of stiffening members of the inner skin are to comply with the requirements for deep tanks or watertight bulkheads, as applicable, *see Pt 3, Ch 7 Bulkheads*.

4.8.3 For details regarding the accessibility and the standard required width of the double skin on Type C tankers, reference is made to *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers*. Requirements are also given for strengthening the double skin in cases where the width is reduced to the minimum value as allowed by the ADN(R). In that case the requirements for reinforcing the sideshell structure by means of additional stringers is also to be complied with.

4.8.4 For details regarding the accessibility and the standard required width of the double skin on Type N tankers, reference is made to *Pt 4, Ch 6, 3.7 Trunk deck plating, trunk side plating and plating of deck abreast trunk of transversely framed trunk deck tankers*.

4.8.5 On type C tankers, profiles or struts connecting structural members of the sideshell with structural members on the longitudinal bulkhead are not allowed.

4.9 Double bottom arrangements

4.9.1 The scantlings of the structure in the double bottom are to be in accordance with *Table 6.4.2 Double bottom (transverse framing)*.

Table 6.4.2 Double bottom (transverse framing)

Item	Parameter	Requirement
(1) Double bottom at centreline	Minimum depth	d_f = 650 mm
(2) Centre girder and side girder	Thickness	$t = (0{,}01 d_f + 1)\sqrt{k}$ mm
(3) Floors	Thickness	$t = (0{,}009 d_f + 1)\sqrt{k}$ mm
(4) Watertight floors and floors in line with web frames	Thickness	$t = (0{,}009 d_f + 1)\sqrt{k}$ mm
For Symbols, *see Table 6.4.1 Hull framing - Transversely framed ships*.		

4.9.2 All parts of double bottom tanks are to be accessible for cleaning and inspection. The tanks are to be well ventilated. Reference is made to*Pt 4, Ch 4, 3 Ship Arrangements* with regard to general requirements concerning the minimum double bottom height, accessibility, the minimum size of openings and minimum free distances between structural members for passage and inspection.

4.9.3 Plate floors are to be fitted at every frame and are to be suitably stiffened, especially in way of manholes. Centre and side girders are to be arranged as required by *Pt 4, Ch 6, 4.3 Centreline girder* and *Pt 4, Ch 6, 4.4 Side girder*.

4.9.4 On type C tankers, profiles or struts connecting structural members of the bottomshell with structural members on the bottom of the cargo tank are not allowed.

■ *Section 5*
Hull envelope framing – Longitudinally framed ships

5.1 General

5.1.1 This Section covers the arrangements and requirements for longitudinal hull framing of the midship region of flush deck and trunk deck tankers.

5.1.2 The scantlings given in *Table 6.5.1 Hull framing - Longitudinally framed ships - Secondary structure* (*see also Pt 4, Ch 6, 5.4 Primary structure 5.4.1*) are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of stiffening members is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

Table 6.5.1 Hull framing - Longitudinally framed ships - Secondary structure

Item	Parameter	Requirement (*See* Notes 1 and 2)
Bottom longitudinals single skin	Modulus	$Z = K\,[0{,}34 + 0{,}46h_b + L_1\,(0{,}112 - 0{,}009h_b)]\,h_b k s l_e^2$ cm^3
Bottom longitudinals double skin	Modulus	$Z = (3{,}95 + 0{,}04L_1)\,D_2 k s l_e^2$ cm^3
Inner bottom longitudinals double skin	Modulus	$Z = 6ksl_e^2 h_g$ cm^3
Side longitudinals single skin	Modulus	$Z = (4 + 0{,}04L_1)\,ksl_e^2 h_g$ cm^3
Side longitudinals double skin	Modulus	$Z = (4{,}6 + 0{,}0342L_1)\,ksl_e^2 h_f$ cm^3
Deck trunk side and trunk deck longitudinals	Modulus Inertia	$Z = [h_g - 3 + (0{,}18 - 0{,}02h_g)\,L_1]\,h_g ksl_e^2$ cm^3 $I = \frac{2,3}{k} l_e Z$ cm^4
For Symbols, *see Table 6.4.1 Hull framing - Transversely framed ships*		
Note 1. In case the scantlings of longitudinal members result in an appreciable excess in the hull midship section modulus as required by*Pt 3, Ch 4 Longitudinal Strength* for the ship type concerned, a reduction in the relevant members may be applied, provided the permissible combined bending stress and the permissible local bending stress are not exceeded. For permissible stresses, *see Pt 4, Ch 6, 12 Direct calculation procedures*. **Note** 2. The minimum compartment thickness of the tank structure is not to be less than as required by *Pt 4, Ch 6, 1.10 Compartment minimum thickness*.		

Table 6.5.2 Hull framing - Longitudinally framed ships - Primary structure

Item	Parameter	Requirement
Bottom transverses	Modulus	$Z = 6{,}6kSl_e^2 h_b$ cm^3
Side transverses	Modulus	$Z = 10kSl_e^2 h_g$ cm^3
Deck and trunk deck transverses	Modulus	The greater of: $Z_b = 6{,}6kSl_e^2 h_g$ cm^3
		$Z_b = 4{,}3kSl_e\ 2\ h_t$cm^3
Trunk side transverses	Modulus	$Z = Z_b$ cm^3
Plate webs in double skin	Thickness	The greater of:
		$t = 7$ mm
		$t = 9\,s_d$
For Symbols, *see Table 6.4.1 Hull framing - Transversely framed ships*		
Note The minimum compartment thickness of the tank structure is not to be less than as required by *Pt 4, Ch 6, 1.10 Compartment minimum thickness*.		

5.1.3 Outside the midship region the structure is to be scarfed into the fore end and aft end structure as provided for in*Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable.

5.1.4 It is recommended that the bottom of ships regularly resting aground be additionally strengthened to withstand the stresses to which it may be subjected. In such ships scallops or openings (unless reinforced) are not to be made in the lower region of the bottom framing.

5.2 Bottom centreline girder

5.2.1 For dry-docking purposes, single hull ships without a centreline bulkhead are to be fitted with a centreline girder having the same height and thickness as the bottom transverses and provided with suitable anti-tripping arrangements.

5.2.2 For dry-docking purposes, double hull ships are to be fitted with a centreline girder. Centreline girders in double bottom structures are to be suitably stiffened. For further details and scantlings, *see Pt 4, Ch 6, 5.6 Double bottom arrangements*.

5.3 Longitudinal framing

5.3.1 Bottom, inner bottom, side shell, deck, trunk side and trunk deck longitudinals are to comply with the requirements of *Table 6.5.1 Hull framing - Longitudinally framed ships - Secondary structure*.

5.3.2 On Type C Tankers, where the width of the double skin is less than 1,0 m, the side shell longitudinals are to comply with *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers*.

5.3.3 Longitudinals are, generally, to be carried through transverse bulkheads. If they stop at transverse bulkheads, brackets are to be fitted inter-connecting the longitudinals. These are to be arranged such that the cross-sectional area of the longitudinals is maintained, *see Pt 3, Ch 10, 3.3 Basis for calculation of bracket connections 3.3.1.(c)*.

5.3.4 Scallops in longitudinals may not be fitted in way of end connections, crossings with transverses or tripping brackets. Where openings for drainage in longitudinals need to be fitted in way of end connections, etc. reinforcements are required.

5.3.5 Longitudinals which are cut in way of deck openings are to be connected to efficient carlings.

5.4 Primary structure

5.4.1 Longitudinal stiffening members are to be supported by transverses arranged to form ring systems. The spacing of the transverses is not to exceed 3,5 m and their scantlings are to be in accordance with *Table 6.5.2 Hull framing - Longitudinally framed ships - Primary structure*. They are to have bracketed end connections, *see Pt 4, Ch 6, 5.1 General 5.1.2* and *Pt 4, Ch 6, 5.4 Primary structure 5.4.8*.

5.4.2 On certain Type C Tankers, the maximum webspacing may be further limited, *see Pt 4, Ch 6, 5.5 Double skin arrangements 5.5.4*.

5.4.3 For the maximum spacing of floors in double bottoms, *see Pt 4, Ch 6, 5.6 Double bottom arrangements 5.6.3*.

5.4.4 The depth of transverses is, generally, to be not less than twice the depth of the slots for the longitudinals.

5.4.5 Transverses fitted on the inboard face of longitudinals are to comply with the requirements of *Pt 3, Ch 3, 3 Structural idealisation* and associated *Figure 3.3.4 Rolled or built sections fitted on top of supported stiffening members*.

5.4.6 When the span of transverses exceeds 3 m, tripping brackets connected to the longitudinals are to be fitted about mid-length of the span.

5.4.7 If pillars are fitted to support deck transverses, they are to comply with*Pt 4, Ch 6, 4.6 Deck support – Flush deck tankers 4.6.4* and their scantlings are to be in accordance with *Table 6.4.1 Hull framing - Transversely framed ships*.

5.4.8 As an alternative to bracketed end connections, side shell transverses may be fitted without brackets, provided their section modulus at the intersection with the bottom transverse is at least equal to the modulus of the bottom transverse, and in way of the deck transverse, at least equal to the modulus of the deck transverse. In this case, the respective face bars of the bottom and deck transverse are to be continued beyond their point of intersection and are to be connected to the nearest sideshell and bottom longitudinal in way. In case the facebars do not line up with any longitudinals they are to be sniped in way of the sideshell or bottomplating. The web plate of the bottom and deck transverse is to be stiffened in line with the face of the side transverse, *see also Pt 4, Ch 6, 7.1 General 7.1.2*.

5.5 Double skin arrangements

5.5.1 The scantlings of the secondary structure in the double skin are to be in accordance with *Table 6.5.1 Hull framing - Longitudinally framed ships - Secondary structure*.

5.5.2 The scantlings of the primary structure in the double skin are to be in accordance with *Table 6.5.2 Hull framing - Longitudinally framed ships - Primary structure*.

5.5.3 Where the inner skin forms the boundary of cargo tanks, the scantlings of stiffening members are to comply with the requirements of *Pt 4, Ch 6, 7 Longitudinal and transverse bulkheads of integral cargo tanks*. Otherwise, the scantlings of stiffening members of the inner skin are to comply with the requirements for deep tanks or watertight bulkheads, as applicable, *see Pt 3, Ch 7 Bulkheads*.

5.5.4 For details regarding the accessibility and the standard required width of the double skin on Type C tankers, reference is made to *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers*. Requirements are also given for strengthening the double skin in cases where the width is reduced to the minimum value as allowed by the ADN. In that case the requirements for reinforcing sideshell structure by means of strengthened sideshell longitudinals in association with a maximum web frame spacing of 1.80 m is also to be complied with.

5.5.5 For details regarding the accessibility and the standard required width of the double skin on Type N tankers, reference is made to *Pt 4, Ch 4, 3.7 Special requirements for Type N tankers*.

5.6 Double bottom arrangements

5.6.1 The scantlings of the structure in the double bottom are to be in accordance with *Table 6.5.3 Double bottom (longitudinal framing)*.

Table 6.5.3 Double bottom (longitudinal framing)

Item	Parameter	Requirements
(1) Double bottom of centreline	Minimum depth	d_f = 650 mm
(2) Centre girder and side girder	Thickness	$t = (0{,}01d_f + 1)\sqrt{k}$ mm
(3) Floors, watertight floors and floors in line with web frames	Thickness	$t = (0{,}009d_f + 2)\sqrt{k}$ mm
For Symbols, *see Table 6.4.1 Hull framing - Transversely framed ships*.		

5.6.2 All parts of double bottom tanks are to be accessible for cleaning and inspection. The tanks are to be well ventilated. Reference is made to *Pt 4, Ch 4, 3.6 Special requirements for Type C tankers* with regard to general requirements concerning the minimum double bottom height, accessibility, the minimum size of openings and minimum free distances between structural members for passage and inspection.

5.6.3 A centreline girder is to be fitted as required by *Pt 4, Ch 6, 5.2 Bottom centreline girder*. Floors are to be fitted at a spacing not exceeding 2,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. Additional stiffening is to be fitted in way of manholes. Where the spacing of the floors exceeds 2,0 m brackets are to be fitted midway between the floors on either side of the centreline girder and at the margins of the double bottom, extending in each case to the nearest bottom and inner bottom longitudinals. The free edges of the brackets are to be suitably stiffened.

■ *Section 6* Hull envelope framing – Combination system

6.1 General

6.1.1 This Section covers the arrangements and requirements for the hull framing of the midship region of flush deck and trunk deck tankers according to the combination system (shell transverse and bottom and deck longitudinal framing).

6.1.2 The scantlings are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of stiffening members is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

6.1.3 Outside the midship region the structure is to be scarfed into the fore end and aft end structure as provided for in *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable.

6.1.4 It is recommended that the bottom of ships regularly resting aground be additionally strengthened to withstand the stresses to which it may be subjected.

6.2 Bottom centreline girder

6.2.1 A bottom centreline girder is to be fitted if required by *Pt 4, Ch 6, 5.2 Bottom centreline girder 5.2.1*.

6.3 Bottom, deck and trunk longitudinals

6.3.1 Longitudinals are to comply with the relevant requirements of *Pt 4, Ch 6, 5.1 General* and *Pt 4, Ch 6, 5.3 Longitudinal framing*.

6.4 Bottom, deck, trunk deck and trunk side transverses

6.4.1 Transverses are to comply with the relevant requirements of *Pt 4, Ch 6, 5.4 Primary structure*. In single hull ships they are to be connected to reinforced side frames, *see Pt 4, Ch 6, 6.5 Side frames, stringers and web frames 6.5.3*. If the shell and longitudinal bulkhead(s) are fitted with a system of stringers and webs, they are to be connected to webframes, *see Pt 4, Ch 6, 6.5 Side frames, stringers and web frames 6.5.1*.

6.5 Side frames, stringers and web frames

6.5.1 Side frames, stringers and web frames are to comply with the relevant requirements of *Pt 4, Ch 6, 4.5 Side frames, stringers and web frames*. Their scantlings are to be in accordance with *Table 6.4.1 Hull framing - Transversely framed ships*.

6.5.2 Side frames are to be fitted with end brackets connected to the outboard longitudinals. When, however, the frames are carried through the bilge radius they may be directly connected to the outboard bottom longitudinal.

6.5.3 In single hull ships, the section modulus of side frames in way of bottom and deck transverses is to be increased by 100 per cent.

6.5.4 If a system of stringers and web frames is fitted, the web frames are to be located in way of, and connected to, bottom and deck transverses.

6.6 Double skin arrangements

6.6.1 The arrangements and scantlings of the double skin are to be in accordance with *Pt 4, Ch 6, 4.8 Double skin arrangement* or *Pt 4, Ch 6, 5.5 Double skin arrangements*, as applicable.

6.7 Double bottom arrangements

6.7.1 The arrangements and scantlings of the double bottom are to be in accordance with *Pt 4, Ch 6, 4.9 Double bottom arrangements* or *Pt 4, Ch 6, 5.6 Double bottom arrangements*, as applicable. The brackets required to be fitted by *Pt 4, Ch 6, 5.6 Double bottom arrangements 5.6.3* at the margins may require to be fitted at every frame.

■ *Section 7*
Longitudinal and transverse bulkheads of integral cargo tanks

7.1 General

7.1.1 This Section covers the arrangements and requirements for plane and corrugated longitudinal and transverse bulkheads. The thickness of plating and the scantlings of vertical and horizontal stiffeners, stringers, webs and transverses and of corrugated bulkheads are to be in accordance with *Table 6.7.1 Scantlings of plane and corrugated transverse and longitudinal bulkheads of integral cargo tanks*.

Table 6.7.1 Scantlings of plane and corrugated transverse and longitudinal bulkheads of integral cargo tanks

Item	Parameter	Requirement
Plating	Thickness	Plane bulkheads $t = 4sf\sqrt{kh_{g}} + K_{c}$ mm Corrugated bulkheads $t = 4w\sqrt{kh_{g}} + K_{c}$ mm
Stiffeners	Modulus	$Z = 6ks\ l_{e}^{\ 2}\ h_{\ g}$
Corrugations *See* Note 2	Modulus Inertia	$Z = 7{,}5ks\ le^{\ 2}\ h_{\ g}$ $I = 3{,}2l_{e}\ Z$ cm^4
Stringers and webs supporting stiffeners	Modulus	$Z = 8{,}5kSl_{e}^{2}h_{g}$
Webs supporting stringers	Modulus	*Z* is to be determined by direct calculations using a stress of $\frac{124}{k}\text{N/mm}^2\left(\frac{12,60}{k}\text{kg/mm}^2\right)$ assuming fixed ends, in association with the head, $h_{\ g}$
Symbols		
Z, I, S, t, s, l_{e}, ρ, k and h_{d} are as defined in *Pt 4, Ch 6, 1.12 Symbols and definitions 1.12.1* f = $1{,}1 - \frac{s}{2.5S}$ h = load height, in metres, measured vertically as follows: = (a) for vertically stiffened plating, the distance from a point 0,5 m above the lower edge of the plate to the top of the tank = (b) for horizontally stiffened plating, the distance from the middle of the first panel above the lower edge of the plate to the top of the tank = (c) for vertically corrugated bulkheads, the distance from a point 0,5 m above the lower edge of the corrugation to the top of the tank = (d) for horizontally corrugated bulkheads, the distance from the middle of the panel of the corrugation to the top of the tank = (e) for stiffening members, the distance from the middle of the effective length to the top of the tank h_{g} = $h\rho + h_{\ d} + 0{,}2$ m w = width of flange (b) or web (c), in metres, whichever is the greater, *see Figure 3.3.3 Dimensions and symbols for corrugated bulkheads* in Pt 3, Ch 3,3 K_{c} = The lesser of 1,5 or d_{t} in *Pt 3, Ch 4, 7.3 Corrosion additions*for mild steel. *See Pt 3, Ch 4, 7.3 Corrosion additions 7.3.7* for solid stainless steel		
Note 1. The minimum compartment thickness of the tank structure is not to be less than as required by *Pt 4, Ch 6, 1.10 Compartment minimum thickness*. Note 2. The required section modulus of corrugations is based on a fully clamped connection at the lower end and a simple support at the upper end of the bulkhead. Other arrangements will receive special consideration.		

Note 3. The basic requirements for the use of higher tensile steels and the associated reduction in required thicknesses and scantlings are, in principle, restricted to transverse bulkheads or longitudinal bulkheads of independent tanks. Structural elements taking part in the global strength of the hull such as integrated longitudinal bulkheads are to be be specially considered for compliance with buckling and/or global stress criteria by which the scantlings may need to be increased.

Note 4. The proof of satisfactory buckling capabilities of corrugated bulkheads executed in higher tensile steel is to be proven by direct calculations.

7.1.2 The scantlings given in *Table 6.7.1 Scantlings of plane and corrugated transverse and longitudinal bulkheads of integral cargo tanks* are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected as indicated in *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*. In tankers of types C and N Closed, all bulkhead stiffeners are to have at least Type I end connections.

7.1.3 Longitudinals may either be carried through transverse bulkheads, or may stop in way. In case longitudinals terminate at transverse bulkheads brackets are to be fitted interconnecting the longitudinals. These are to be arranged such that the cross-sectional area of the longitudinals is maintained, *see Pt 3, Ch 10, 3.3 Basis for calculation of bracket connections 3.3.1.(c)*.

7.1.4 When the ship is longitudinally framed in deck and bottom, the vertical stiffeners on transverse bulkheads are to be in line with the deck and bottom longitudinals.

7.1.5 Where, in accordance with *Table 6.7.1 Scantlings of plane and corrugated transverse and longitudinal bulkheads of integral cargo tanks*, higher tensile steels are used in the construction of plane or corrugated bulkheads, structural items forming the supporting structure in double bottoms or within the double hull may require to be made of equivalent materials depending on the maximum stress levels in way.

7.1.6 Scallops in stiffeners may not be fitted in way of end connections, crossings with primary members and tripping brackets.

7.1.7 The depth of primary members is generally to be not less than twice the depth of the slots for the stiffening members.

7.2 Stainless steel

7.2.1 The material is to comply with the requirements of *Pt 4, Ch 6, 1.9 Stainless steel*.

7.2.2 The thickness of plating forming boundaries of cargo tanks is to be in accordance with the requirements given in *Pt 4, Ch 6, 7.1 General*.

7.2.3 Where tank boundary plating may be subjected to primary buckling stresses, or is required to form an effective flange of a primary member, it may be necessary to increase the plating thickness for compliance with general buckling aspects.

7.2.4 The thickness of plating is not to be less than the minimum compartment thickness, *see Pt 4, Ch 6, 1.10 Compartment minimum thickness*.

7.2.5 The section modulus of mild steel stiffeners attached to stainless steel plating is to be based on the actual plating thickness.

7.3 Cofferdam bulkheads

7.3.1 Requirements for the location, arrangement and testing of cofferdams are given in *Pt 4, Ch 4, 3 Ship Arrangements*.

7.3.2 The scantlings of cofferdam bulkheads are to comply with the requirements of *Pt 4, Ch 6, 7.1 General* and *Pt 4, Ch 6, 7.2 Stainless steel*, as applicable.

7.3.3 Cofferdam bulkheads not bounding the cargo tank are to comply with the requirements of *Table 6.7.1 Scantlings of plane and corrugated transverse and longitudinal bulkheads of integral cargo tanks* using ρ =1,0 and h_d = 1,0 m.

7.4 Stringers and webs

7.4.1 Vertical stiffeners may be supported by an effective system of stringers and webs. The stringers are to be in line with the stringers of the ship's sides, if fitted.

7.4.2 Horizontal stiffeners of longitudinal bulkheads are to be supported by webs which are to form part of the ring system of transverses required by *Pt 4, Ch 6, 5.4 Primary structure 5.4.1*.

7.4.3 Webs fitted on the inboard face of longitudinals are to comply with the requirements of *Pt 3, Ch 3, 3 Structural idealisation* and associated *Figure 3.3.4 Rolled or built sections fitted on top of supported stiffening members*.

■ *Section 8* Construction of tankers with cargo tanks independent from the ship's structure

8.1 General

8.1.1 This Section covers the requirements for the hull construction of tankers with independent tanks and semiindependent tanks. For relevant cross sections, *see Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N* of Chapter 4 whereby the cargo tanks have been designated as 'Type of Cargo Tank 1'. The thickness of the hull envelope plating and the scantlings of structural members are to be equivalent to those given in Chapter 1, except as stated otherwise in this Section.

8.1.2 Tanks may be supported by bearers of substantial construction. The bearers and supporting brackets are to be arranged in line with floors and girders in the bottom structure. Consideration will be given to proposals to fit flat bottom tanks directly on to the top of bottom structure, taking into account structural interaction resulting from different structural stiffnesses.

8.1.3 Chocks and other securing arrangements are to be fitted to avoid unintentional displacement of the tanks caused by accidents such as collision and/or flooding of the holds. The hull structure in way is to be reinforced accordingly. When the cargo in the tanks can be heated, chocking arrangements are to take account of expansion of the tanks.

8.1.4 The space between the tanks and the surrounding ship's structure should be adequate to enable complete inspection of ship and tank structure.

8.2 Midship section modulus calculation

8.2.1 For the calculation of the midship section modulus, *see Pt 3, Ch 3, 3.4 Calculation of hull section modulus*. Where the top of semi-independent tanks is continuous within the midship region and efficiently connected to the ship's structure, the plating and longitudinal stiffeners of the top of the tank, and tank side to 0,1D m under deck, may be included in the calculation.

8.3 Topside structure

8.3.1 For ships where the cargo tanks are independent and whereby the topside structure is not efficiently connected to the cargo tanks, the scantlings of the topside structure are to comply with the requirements of *Pt 4, Ch 1, 4 Deck plating and continuous longitudinal hatch side coamings* . For all other configurations the scantlings are to comply with the requirements of *Pt 4, Ch 6, 3 Hull envelope framing*. Where transverse stiffening is provided in the top of the tanks, their scantlings are to be in accordance with *Pt 4, Ch 6, 4 Hull envelope framing – Transversely framed ships*. Where longitudinal stiffening is provided in the top of the tanks, their scantlings are to be in accordance with *Pt 4, Ch 6, 5 Hull envelope framing – Longitudinally framed ships*.

8.4 Hull envelope plating

8.4.1 Apart from the requirements set out in *Pt 4, Ch 6, 8.3 Topside structure*, the hull envelope plating is to be in accordance with *Pt 4, Ch 1, 5 Hull envelope plating*.

8.5 Double skin arrangement

8.5.1 The plating of the inner skin is to comply with the requirements for deep tank or watertight bulkheads, as applicable, *see Pt 3, Ch 7 Bulkheads*.

8.5.2 In addition, arrangements and scantlings of the double skin are to be in accordance with *Pt 4, Ch 6, 4.8 Double skin arrangement* or *Pt 4, Ch 6, 5.5 Double skin arrangements*, as applicable.

8.6 Single bottom structure

8.6.1 A transverse or longitudinal framing system may be adopted, but ships with a length, L, of more than 70 m and transverse framing are to have additional longitudinal stiffening fitted at the bottom. The scantlings of floors, transverses and

longitudinals are to comply with the requirements of *Table 6.8.1 Single bottom structure of ships with independent cargo tanks*. The remaining structural items are to comply with *Pt 4, Ch 1, 6 Single bottom structure*.

Table 6.8.1 Single bottom structure of ships with independent cargo tanks

Item	Parameter	Requirement
(1) Floors	Web depth at centreline Web thickness Modulus	$d_w = 40B$ mm $t = 0{,}01d_w + 2{,}5$ mm The greater of: a) $Z = 7Ts B^2$ cm^3 b) $Z = \left(17{,}5 - \frac{8{,}3b}{B}\right) h_f b\, Bs - 5TB^2 s$ cm^3
(2) Transverses	Modulus	The greater of: a) $Z = 7T S B^2$ cm^3 b) $Z = \left(17{,}5 - \frac{8{,}3b}{B}\right) h_f b\, Bs - 5TB^2 S$ cm^3 *See* Notes 1 and 2
(3) Longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)\, D_1\, s l_e^2$ cm^3 *See* Notes 1 and 2
Symbols		
$L, B, D, T, S, s, l_e, Z, \rho$ and t = as defined in *Pt 4, Ch 6, 1.12 Symbols and definitions 1.12.1* b = breadth of tank support on the floor, in metres d = mean height of the cargo tank, in metres d_w = web depth of floor at centreline, in mm D_1 = D, but need not be taken greater than T + 0,4 m h_f = d, in metres L_1 = l, but to be taken not less than 65 m		
Note 1. Where effective support at the centreline of the ship is provided, the required section modulus of the floors and transverses will be considered on the basis of a reduced effective span. Note 2. The formulae are based on the assumption that the load from the tanks is evenly distributed over all floors and transverses in way.		

8.6.2 Floors in a transverse framing system are to be fitted at every frame. Transverses in a longitudinal framing system are to be spaced not more than 2,5 m apart. If the depth of floors is to be locally decreased to suit the shape of the tank which is supported by them, the strength of floors and transverses in way is to be maintained. When the loads exerted by the tanks are not evenly distributed, the strength of the bottom structure is to be verified by direct calculation.

8.6.3 On single hull ships, the section modulus of side frames in way of bottom transverses is to be increased by 100 per cent.

8.6.4 A single bottom structure is not allowed on Tankers of Type C.

8.7 Double bottom structure

8.7.1 A transverse or longitudinal framing system may be adopted, but ships with a length, *L*, exceeding 70 m are generally to be longitudinally framed. The requirements of *Pt 4, Ch 1, 7 Double bottom structure* are generally to be complied with. When cargoes of a higher specific gravity than 1,0 tonnes/m^3 are carried or when the load from the tanks is not evenly distributed over the bottom structure, the strength of the bottom structure is also to be verified by direct calculation.

8.7.2 In addition, arrangements of the double bottom are to be in accordance with *Pt 4, Ch 6, 4.9 Double bottom arrangements* or*Pt 4, Ch 6, 5.6 Double bottom arrangements*, as applicable.

■ *Section 9* Construction of cargo tanks independent from the ship's structure

9.1 General

9.1.1 This Section covers the arrangements and requirements for independent and semi-independent cargo tanks which are designated as: Tanks of open or closed type for the carriage of nondangerous liquids and of dangerous liquids of Class 3, 6.1, 8 and 9.

9.1.2 For a possible restriction of the capacity of tanks, *see Pt 4, Ch 4, 3 Ship Arrangements*.

9.1.3 If cargo is to be discharged under pressure, the tanks are regarded as pressure tanks.

9.2 Structural requirements

9.2.1 Pressure tanks are to comply with the requirements for pressure vessels, *see* Ship Type in *Pt 4, Ch 5 Tankers of Type G*.

9.2.2 Tanks of open or closed type may have plane or corrugated bulkheads and be constructed with stiffening fitted internally or externally, or a combination of the two.

9.2.3 The scantlings and arrangements of open and closed type tanks are to be in accordance with *Pt 4, Ch 6, 7 Longitudinal and transverse bulkheads of integral cargo tanks*. However, when the tanks are of the semi-independent type (*see Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N* in Chapter 4) the scantlings of the top of the tanks are to be in accordance with the second part of *Pt 4, Ch 6, 8.3 Topside structure 8.3.1*.

9.2.4 The section modulus of stiffening members of wash bulkheads, if fitted, may be 50 per cent of that required for boundary bulkheads in the same position. The ends of stiffeners may be unattached except those which support girders or longitudinal stiffeners of the tank boundary.

■ *Section 10* Bunkermasts

10.1 General

10.1.1 A bunkermast is a device consisting of a movable mast or jib provided with cargo lines intended for loading or discharging oil products from the cargo tanks such as diesel oil, fuel oil, petroleum crude oil, petroleum distillates, lubricating oil and bilge water.

10.1.2 The structure of bunkermasts is not covered by this Section. Approval of the structure and structural components of bunkermasts is to be dealt with by the competent authority or inspection body. When authorised, LR is prepared to issue a statement of compliance with a Recognised Standard. Alternatively, upon special request, the bunkermast could be considered for equivalence with the requirements as contained in the *Code for Lifting Appliances in a Marine Environment*.

10.2 Bunkermast pedestals

10.2.1 This Section applies to pedestals for bunkermasts.

10.2.2 Pedestals, in general, are to be carried through the deck and satisfactorily scarphed into the hull or main support structure. Proposals for other support arrangements will be specially considered.

10.2.3 The pedestal flange in way of the slew ring bearing is to be designed and be of a thickness to provide a rigid and level support for the bearing and bolting. Tolerances and arrangements proposed by the slew ring bearing manufacturer are to be adhered to.

10.2.4 Where it is considered necessary to introduce stiffening brackets to support the flange the spacing of the brackets is to be not greater than that achieved by positioning them between every second bolt.

10.2.5 The pedestal is to be designed with respect to the worst possible combination of loads resulting from the bunker crane self weight, loads from attached hoses and internal piping fully filled with oil, bunker crane accelerations together with loads resulting from the ship's heel and trim if anticipated to be greater than 5° and 2° respectively.

10.2.6 In the design of the pedestal, the following allowable stresses should not be exceeded:

Bending stress

$$\sigma_b = 0,58\sigma_y$$

Shear stress

$$\tau = 0,34\sigma_y$$

where

σ_y = yield stress of material, in N/mm^2

10.3 Additional requirements

10.3.1 Underdeck spaces in which the swivel mechanism is located are not to be open to cargo tanks, unless the cargo list of the ship is restricted to products mentioned in *Pt 4, Ch 6, 10.1 General 10.1.1* only.

10.3.2 Underdeck or enclosed spaces in which the swivel is located are not to be permanently open to cofferdams or double bottom spaces and are to be accessible for inspection purposes under all service conditions. The dimension of the access opening is to comply with *Pt 4, Ch 4, 3.2 Hold spaces, cargo tanks and service spaces 3.2.6*. This opening is to be closed by a removable manhole cover or hatch provided with adequate sealing arrangements.

10.3.3 Underdeck or enclosed spaces in which the swivel mechanism is located are to be provided with sounding and independent drainage arrangements.

■ *Section 11* **Miscellaneous**

11.1 Hatchways and closing appliances

11.1.1 For requirements in respect of coamings and closing of deck openings, *see Pt 4, Ch 4, 3.3 Protection against the ingress of gases within accommodations and entrances*.

11.2 Pillar bracket inside the cargo tank

11.2.1 Where the deck transverse and bottom floor are supported by the pillar, the pillar is to be verified by direct calculations considering the service, test and vacuum conditions.

11.2.2 In between pillars, pillar brackets and pillar brackets, inner bottoms, the shear area are to be verified by direct calculations considering the axial force from the pillar. For permissible stresses, *see Pt 4, Ch 6, 12.2 Loads 12.2.1*.

11.2.3 Where the length of the free edge of a bracket exceeds 50t mm, edge stiffening is to be fitted or the thickness is to be suitably increased.

Section 12
Direct calculation procedures

12.1 General

12.1.1 This Section contains guidance for direct calculation, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

12.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules, calculation results are to be submitted for approval together with all data in support of the calculation, i.e. support conditions and applied loads.

12.2 Loads

12.2.1 Load heads to be used in direct calculations to determine the required section moduli of structural members listed in *Table 6.12.1 Maximum permissible stresses in longitudinal continuous members, in N/mm²* and *Table 6.12.2 Maximum permissible stresses in local members, in N/mm²*, are to be in accordance with *Pt 4, Ch 6, 4 Hull envelope framing – Transversely framed ships* to *Pt 4, Ch 6, 8 Construction of tankers with cargo tanks independent from the ship's structure*, as applicable.

Table 6.12.1 Maximum permissible stresses in longitudinal continuous members, in N/mm²

Item	Local bending stress, σ_b	Combined bending stress, σ_c *See* Note 1	Shear stress, τ	Equivalent stress, σ_e *See* Note 2
Bottom and deck girders in transversely framed ships	$0,46\sigma_L$	$0,75\sigma_L$	$0,35\sigma_L$	$0,80\sigma_L$
Bottom, deck and side longitudinals	$0,58\sigma_L$	$0,75\sigma_L$	$0,35\sigma_L$	$0,80\sigma_L$
Symbols				
Where $\sigma_L = 235/k_L$				
Note 1. The combined stress, σ_c, is the sum of the stresses due to longitudinal bending and local loading.				
Note 2. The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$				

Table 6.12.2 Maximum permissible stresses in local members, in N/mm²

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *See* Note
Floors, bottom transverses, non-continuous bottom girders, side stringers, deck beams, deck transverses and non-continuous deck girders	$0,53\sigma_o$	$0,35\sigma_o$	$0,75\sigma_o$
Side frames	$0,48\sigma_o$	$0,35\sigma_o$	$0,73\sigma_o$
Webs supporting side stringers, side transverses	$0,43\sigma_o$	$0,35\sigma_o$	$0,71\sigma_o$
Note The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$			

12.3 Permissible stresses

12.3.1 In addition to the permissible stresses given in *Pt 3, Ch 4, 6 Hull bending strength* , the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 6.12.1 Maximum permissible stresses in longitudinal continuous members, in N/mm²*.

(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 6.12.2 Maximum permissible stresses in local members, in N/mm²*.

12.3.2 Where finite plate element calculations are carried out, local peak stresses in excess to those given in *Pt 4, Ch 6, 12.3 Permissible stresses 12.3.1*will be specially considered.

12.4 Structural requirements

12.4.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

12.4.2 In addition to the maximum permissible stresses given in *Pt 4, Ch 6, 12.3 Permissible stresses*, the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see Pt 3, Ch 5, 2 Hull envelope plating*.

(b) The thickness of the bilge plating amidships is to be 2 mm more than the bottom plating in way.

(c) The thickness of the deck plating is to be not less than the thickness of deck plating at ends, *see Pt 3, Ch 5, 2 Hull envelope plating*, nor less than the minimum compartment thickness, *see Pt 4, Ch 6, 1.10 Compartment minimum thickness*. Depending on the level of compressive stresses and panel dimensions, additional buckling calculations may be required.

Section 1 General

1.1 Application

1.1.1 This Chapter applies to propelled and nonpropelled tankers intended for the carriage in bulk of:

Commodity	*Ship Type*
Fresh water	Water tanker
Wine	Wine tanker
Edible and vegetable oils with a flash point above 100°C	Edible oil tanker

1.1.2 Fresh water, wine, edible and vegetable oils are generally transported in a Type N open tanker having integrated (ADN Type 2) cargo tanks as shown in *Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N* in Chapter 4. If carriage of the commodities in tanks independent or semi-independent from the ship's structure is required for special reasons (e.g. heating of cargo, stringent requirements for product purity, etc.), a Type N open tanker is required with tanks generally of ADN Type 1 or 3 as shown in *Figure 4.1.2 Examples of possible hull configurations for Tankers of the Types G. C and N* in Chapter 4.

1.1.3 The scantlings and arrangements of the ships are to comply with the requirements of *Pt 4, Ch 6 Tankers of Types C and N* for a Type N Open tanker carrying non-dangerous liquids in bulk so far as applicable or as otherwise specified in this Chapter.

1.2 Ship arrangement

1.2.1 Cofferdams are generally to be fitted at ends of the cargo compartment for cargo purity reasons.

1.2.2 Cargo tanks may not have common boundaries with any other tank.

1.2.3 For preservation of wine, it is recommended that the cargo tanks be so arranged that in the loaded condition the free surface of the cargo is as small as practicable.

1.3 Class notation

1.3.1 Ships complying with the requirements of this Chapter will be eligible to be classed as follows when the requirements for the particular type of ship have been fulfiled:

‘A1 I.W.W. – Water tanker, or

‘A1 I.W.W. – Wine tanker’, or

‘A1 I.W.W. – Edible oil tanker’, or

‘A1 I.W.W. – Water barge’, or

‘A1 I.W.W. – Wine barge’, or

‘A1 I.W.W. – Edible oil barge’.

1.3.2 Where appropriate, the type of cargo(es) may be included in the class notation.

1.3.3 The Regulations for classification and assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations* to which reference should be made on the Survey Request form.

1.4 Information required

1.4.1 For the information required, *see Pt 4, Ch 6, 1.11 Information required*. In addition the following are to be applied so far as applicable:

(a) Particulars of coating or lining to be applied on the structure of the cargo tanks and method of application.
(b) List of edible and vegetable oils intended to be carried in the particular 'Edible oil tanker'.
(c) Details of chocking arrangements for independent tanks.
(d) Particulars of heating arrangements if applied in ‘Edible oil tankers’ together with the maximum temperature to which the cargo will be heated.

■ *Section 2* Materials and protection

2.1 General

2.1.1 In addition to the requirements of *Pt 4, Ch 4, 2 Materials* so far as applicable, the internal structure of mild steel cargo tanks is to be protected against corrosion by the application of a suitable coating or lining which is also suitable for preservation of product purity.

■ *Section 3* Longitudinal strength

3.1 General

3.1.1 The longitudinal strength of water tankers, wine tankers and edible oil tankers is to comply with the requirements of *Pt 3, Ch 4 Longitudinal Strength* and for this purpose these ships are to be considered as Category ‘T’ ships. The requirements of *Pt 4, Ch 6, 2.1 Longitudinal strength requirements* are also to be applied.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to self-propelled tugs, pusher tugs and launches, defined as follows:

(a) A tug is a ship designed primarily for the towage of other ships, which does not exclude occasional pushing duties, if arranged for this purpose.
(b) A pusher tug is a ship designed for the pushing of other ships.
(c) A launch is a ship designed primarily for the transport of personnel and small quantities of cargo.

1.1.2 The structural requirements of this Chapter are intended to cover ships having a length not exceeding 50 m, a ratio of length to depth not exceeding 18 and a ratio of breadth to depth not exceeding five.

1.1.3 Launches having a speed exceeding 20 km/h may be constructed according to the requirements for fast small craft, incorporated in the *Rules and Regulations for the Classification of Special Service Craft*.

1.1.4 The scantlings of the ship's structure are to be not less than required in *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable or as specified otherwise in this Chapter.

1.1.5 The remaining requirements of*Pt 3 Ship Structures (General)* are also to be complied with as appropriate to the intended arrangements.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a, generally, single decked hull with a single bottom, single skin side construction and a transverse or longitudinal framing system.

1.2.2 For pusher tugs and tugs with relatively high engine power having twin or multiple screws, it is recommended that a double skin side construction be adopted and/or to fit continuous longitudinal bulkheads extending as far forward and aft as practicable.

1.3 Hull vibration

1.3.1 Pusher tugs and tugs with their relatively high engine power are liable to experience a high level of vibration and noise. Attention is drawn to the fact that certain National Authorities specify a maximum level of noise. It is therefore recommended that special attention be given to acoustic insulation and to flexible mounting of the deckhouse, etc.

1.4 Class notation

1.4.1 Ships complying with the requirements of this Chapter will be eligible to be classed 'A1 I.W.W. tug', 'A1 I.W.W. pusher tug' or 'A1 I.W.W. launch'.

1.4.2 The Regulations for classification and assignment of class notations are given in*Pt 1, Ch 2 Classification Regulations* to which reference should be made on the survey request form.

1.4.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1, for service extension or for navigation in ice, the appropriate class notation will be assigned.

1.5 Information required

1.5.1 For the information required, *see Pt 3, Ch 1, 5 Information required*. In addition the following are to be supplied:

(a) The maximum pressure head in service on tanks, also details of any tanks interconnected with side tanks.
(b) The pull, which can be exerted on the towline or the push at the push stem.
(c) Arrangements for the stowage of cargo and details of the deck loads.
(d) Details of cranes or masts for the handling of the cargo, if fitted, and their supporting arrangement.
(e) Support structure and foundations of towing equipment.
(f) Skegs, propeller guards and other structures which support the weight of the vessel during dry-docking.

1.5.2 The following supporting documents are to be submitted for information:

(a) Towing arrangements, including lines of action, magnitudes and corresponding points of application of towline pulls on towing equipment.
(b) Details of the breaking strength of the components of the towline system, together with maximum pull and brake holding load, or equivalent, of towing winches where applicable.

1.6 Symbols and definitions

1.6.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, T = as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

t = thickness of plating, in mm

$P\rho$ = maximum designed shaft power of the propulsion machinery installed in the ship, in kW

($H\rho$ = maximum designed shaft power of the propulsion machinery installed in the ship, in shp).

■ Section 2
Hull envelope plating

2.1 Shell plating

2.1.1 The thickness of bottom and side shell plating is to be as required by *Pt 3, Ch 5, 2 Hull envelope plating* and *Pt 3, Ch 6, 4 Single and double bottom structure* but for tugs and pusher tugs the thickness is to be not less than:

$$t = 4,8 + 0,045L + \sqrt{\frac{1,36P_{\rho}}{L+10}} \text{ mm}$$

$$\left(t = 4,8 + 0,045L + \sqrt{\frac{H\rho}{L+10}} \text{ mm}\right)$$

2.1.2 The thickness of the keel plate is to be the same as required for the bottom plating. When, however, there is a rise of floor the thickness of the keel plate is to be increased by 1 mm.

2.1.3 The thickness of the bilge plating for tugs and pusher tugs is to be 1 mm more than the required thickness of the bottom shell plating. The bilge radius is to be at least ten times the thickness of the bilge plating. The bilge plating is to extend at least 100 mm on either side of the radius of the bilge plate. For the extent of bilge plating in the fore and aft direction, *see Pt 3, Ch 5, 2.4 Shell plating*.

2.1.4 Efficient and effectively supported fenders are to be fitted at deck level.

2.2 Deck plating

2.2.1 The thickness of deck plating is to be as required by *Pt 3, Ch 5, 2 Hull envelope plating*, but for tugs and pusher tugs the thickness of the deck is to be not less than 5,5 mm.

2.2.2 The deck thickness is to be locally increased in way of winch seatings and crane supports. The increased thickness is to be not less than 8 mm.

■ *Section 3* Hull envelope framing

3.1 Bottom structure

3.1.1 A centreline girder is generally required in ships having a breadth, *B*, or more than 4 m. A side girder, of the same scantlings as the centreline girder is to be fitted on each side of the centreline in ships with a breadth, *B*, of more than 10 m. Engine seating girders are to form an integral part of the bottom girder system.

■ *Section 4* Towing arrangements

4.1 General

4.1.1 Towing bitts, a towing hook or a towing winch are to be fitted on a tug and should normally be situated 5 to 10 per cent of the ship's length abaft amidships, but it is the designer's responsibility that positive vertical and lateral stability in all circumstances is ensured.

4.1.2 Towing hooks and towing winches should have reliable slip arrangements, which facilitate towline release regardless of the angle of heel.

4.2 Deck structure

4.2.1 The deck structure in way of the towing bitt or towing winch is to be suitably strengthened and supported by means of pillars and girders. The scantlings of this deck structure may be determined by direct calculation using the information given in *Pt 4, Ch 8, 7 Direct calculation procedures*.

■ *Section 5* Pushing arrangements

5.1 General

5.1.1 Push stems are to be fitted on pusher tugs and are to comply with the requirements given in *Pt 3, Ch 5, 4.6 Stem arrangement for pushing purposes*. It is recommended that ships primarily used for pushing will be equipped with a twin push stem as indicated in *Figure 5.4.2 Loads on stem for pushing purposes* in Pt 3, Ch 5.

5.1.2 Ships constructed for pushing duties are to be equipped with adequate coupling arrangements, such as winches and wires.

5.2 Deck structure

5.2.1 The deck structure in way of winches for coupling wires and under windlasses is to be suitably strengthened.

Section 6
Propulsion systems

6.1 General

6.1.1 When a propulsion system is fitted like 'Voith Schneider', rudder propellers, etc. note should be taken of the manufacturer's recommendations regarding the position of towing bitt or towing winch, the stability of the ship and the position of skegs.

6.1.2 Propulsion systems protruding under the bottom of the ship are to be protected against damage by an effective structure around the propulsion system. The protective structure is to be strong enough to withstand the loads imposed on it by dry-docking.

6.2 Bottom structure

6.2.1 The bottom structure is to be reinforced around large openings arranged for the fitting of the propulsion system. In general, deep floors in association with longitudinal girders are to be fitted, the scantlings of which may be obtained by direct calculation, using maximum permissible stresses given in *Pt 4, Ch 8, 7 Direct calculation procedures*.

6.2.2 The protective structure mentioned in *Pt 4, Ch 8, 6.1 General 6.1.2* is to be adequately supported.

Section 7
Direct calculation procedures

7.1 General

7.1.1 This Section contains guidance for direct calculations and information regarding maximum permissible stresses for structural members in the deck and bottom.

7.1.2 Where direct calculation is adopted, all data in support of the calculation, i.e. support conditions and loads are to be submitted, together with the calculation.

7.2 Permissible stresses

7.2.1 For local structural members in bottom and deck, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 8.7.1 Maximum permissible stresses in local members in bottom and deck, in N/mm2*.

Table 8.7.1 Maximum permissible stresses in local members in bottom and deck, in N/mm^2

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *See* Note
Bottom transverses, bottom girders, deck girders, deck transverses	$0{,}52\sigma_o$	$0{,}35\sigma_o$	$0{,}75\sigma_o$
Deck beams, floors, deck longitudinals, bottom longitudinals	$0{,}58\sigma_o$	$0{,}35\sigma_o$	$0{,}80\sigma_o$
Note The equivalent stress σe is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$			

7.3 Design criteria for the bottom structure

7.3.1 The draught of the ship is to be taken as T + 0,4 m.

7.3.2 The horizontal and vertical loads on a protective structure as mentioned in *Pt 4, Ch 8, 6.1 General 6.1.2* may be taken as the maximum weight of the ship.

7.4 Design criteria for the deck structure

7.4.1 For the assessment of the deck structure in way of the towing bitt, towing winch or towing hook, the pull in the towing wire used in the calculation is to be taken as 0,8 times the breaking strength of the towing wire, in conjunction with the permissible stresses given in *Table 8.7.1 Maximum permissible stresses in local members in bottom and deck, in N/mm2*.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to propelled passenger ships, with or without sleeping accommodation, having the machinery aft or amidships.

1.1.2 The scantlings and arrangements are to be as required in *Pt 4, Ch 1 Dry Cargo Ships* as far as applicable and as specified otherwise in this Chapter.

1.1.3 The structural requirements of this Chapter are intended to cover the midship region as defined in *Pt 3, Ch 3, 2.2 Definition of midship region*of ships not exceeding 135 m in length, having a ratio of length to depth not exceeding 35 and in general, a ratio of breadth to depth not exceeding five.

1.1.4 The structural requirements forward and aft of the midship region are to comply with *Pt 3, Ch 5 Fore End and Aft End Structure* and *Pt 3, Ch 6 Machinery Spaces* so far as applicable. The remaining requirements of *Pt 3 Ship Structures (General)* are also to be complied with as appropriate to the intended arrangements.

1.1.5 The requirements in this Chapter are based on the European Standard laying down Technical Requirements for inland Navigation Vessels (ES-TRIN), in particular Chapter 19, concerning special requirements applicable to Passenger Vessels.

1.1.6 Although the contents of this Chapter takes part of the regulations mentioned in *Pt 4, Ch 9, 1.1 Application 1.1.5* into account, the issue of a Certificate on behalf of the relevant Authorities requires full compliance with these Regulations.

1.1.7 Attention is drawn to other National and International technical and operational requirements of countries where the ship is registered or operating. These requirements are outside classification as defined in these Rules and Regulations but may however be accepted in lieu of the requirements in *Pt 4, Ch 9, 1.1 Application 1.1.5* as deemed acceptable by LR.

1.1.8 At the request of the owner or builder and as delegated by the competent National Authority as referred to in *Pt 4, Ch 9, 1.1 Application 1.1.5* and *Pt 4, Ch 9, 1.1 Application 1.1.7*, LR can also issue a Statement of Compliance with specific National or International requirements.

1.2 Ship arrangement – Definitions

1.2.1 For the purpose of this Chapter, the following definitions apply:

(a) ‘bulkhead deck’: the deck to which the required watertight bulkheads are taken and from which the freeboard is measured;

(b) 'freeboard': the distance between the plane of maximum draught and a parallel plane passing through the lowest point of the gunwale or, in the absence of a gunwale, the lowest point of the upper edge of the ship's side;

(c) 'residual freeboard': the vertical clearance available, in the event of the vessel heeling over, between the water level and the upper surface of the deck at the lowest point of the immersed side or, if there is no deck, the lowest point of the upper surface of the fixed ship's side;

(d) 'margin line': an imaginary line drawn on the side plating not less than 10 cm below the bulkhead deck and not less than 10 cm below the lowest non-watertight point of the side plating. If there is no bulkhead deck, a line drawn not less than 10 cm below the lowest line up to which the outer plating is watertight shall be used;

(e) 'passenger area': areas on board intended for passengers and enclosed areas such as lounges, offices, shops, hairdressing, salons, drying rooms, laundries, saunas, toilets, washrooms, passageways, connecting passages and stairs not encapsulated by walls;

(f) 'machinery space': the space extending from the baseline to the margin line and between the transverse watertight bulkheads containing the main propelling and auxiliary machinery, boilers and coal bunkers if any.

(g) 'permeability of a space': the percentage of a space which can be occupied by water.

(h) 'stairwell': the well of an internal staircase or of a lift;

(i) 'passageway': an area intended for the normal movement of persons and goods;

(j) 'safe area': the area which is externally bounded by a vertical surface running at a distance of 1/5 of the maximum moulded breadth of the waterline at the maximum design draught parallel to the course of the hull at right angles to the centreline.

1.3 Ship arrangement – Stability and freeboard

1.3.1 The intact and damage stability of the vessel is to be approved by the competent National Authorities in accordance with the regulations as stipulated in *Pt 4, Ch 9, 1.1 Application 1.1.5*.

1.3.2 Proof of sufficient stability may also be furnished by other National or International stability requirements of countries where the ship is registered or operating. These requirements may be accepted in lieu of the requirements in *Pt 4, Ch 9, 1.1 Application 1.1.5* as deemed acceptable by LR.

1.3.3 At the request of the owner or builder and as delegated by the competent National Authority as referred to in *Pt 4, Ch 9, 1.3 Ship arrangement – Stability and freeboard 1.3.1* and *Pt 4, Ch 9, 1.3 Ship arrangement – Stability and freeboard 1.3.2* LR can also issue a Statement of Compliance with specific National or International stability requirements.

1.3.4 The freeboard of the vessel shall at least be 300 mm and shall furthermore not be less as required in association with intact and damage stability requirements in accordance with *Pt 4, Ch 9, 1.3 Ship arrangement – Stability and freeboard 1.3.1* or *Pt 4, Ch 9, 1.3 Ship arrangement – Stability and freeboard 1.3.2*.

1.3.5 The maximum draught is to be in compliance with the requirements of *Pt 4, Ch 9, 1.3 Ship arrangement – Stability and freeboard 1.3.4* and is to be marked on the ship's sides at about mid-length.

1.4 Ship arrangement – Subdivision and transverse bulkheads

1.4.1 Further to the requirements of *Pt 3, Ch 7, 1.2 Number and disposition of bulkheads* the number and position of bulkheads shall be such that, in the event of flooding, the vessel remains afloat in compliance with *Pt 4, Ch 9, 1.3 Ship arrangement – Stability and freeboard*. Every portion of the internal structure which affects the efficiency of the subdivision shall be watertight, and shall be of a design which will maintain the integrity of the subdivision.

1.4.2 The distance between the collision bulkhead and the forward perpendicular shall be at least $0{,}04L_{WL}$ and not more than $0{,}04L_{WL}$ + 2 m. If the distance exceeds $0{,}04L_{WL}$ + 2 m, compliance with *Pt 3, Ch 7, 1.3 Collision bulkhead 1.3.1* shall be proven by direct calculations.

1.4.3 The distance from the F.P. may be reduced to $0{,}03L$, in which case the requirement of *Pt 3, Ch 7, 1.3 Collision bulkhead 1.3.1* shall be proven by direct calculations based on the flooding of both the fore peak and those compartments directly aft of and adjacent to the collision bulkhead.

1.4.4 A transverse bulkhead may be fitted with a bulkhead recess, if all parts of this offset lie within the safe area.

1.4.5 The bulkheads, which are taken into account in the damaged stability calculation according to *Pt 4, Ch 9, 1.3 Ship arrangement – Stability and freeboard* shall be watertight and shall extend up to the bulkhead deck. Where there is no bulkhead deck, these bulkheads shall extend to a height at least 20 cm above the margin line.

1.4.6 The number of openings in the bulkheads referred to above shall be kept to the minimum consistent with the type of construction and normal operation of the vessel. Openings and penetrations shall not have a detrimental effect on the watertight subdivisional aspects of the bulkheads.

1.4.7 Bulkheads according to *Pt 4, Ch 9, 1.4 Ship arrangement – Subdivision and transverse bulkheads 1.4.5* separating the engine rooms from passenger areas or crew and shipboard personnel accommodation shall have no doors.

1.4.8 Where double bottoms are fitted, their height shall be at least 0,60 m, and where a double hull has been fitted, its width shall be at least 0,60 m.

1.4.9 Portholes and windows may be situated below the margin line if they are watertight, cannot be opened, possess sufficient strength and are in compliance with a recognized standard.

1.5 Ship arrangement – Watertight doors and doors

1.5.1 Doors in bulkheads referred to in *Pt 4, Ch 9, 1.4 Ship arrangement – Subdivision and transverse bulkheads 1.4.5*, and their actuators shall be located in the safe area.

1.5.2 Doors in watertight bulkheads are to be approved by the relevant National Authorities in compliance with *Pt 4, Ch 9, 1.1 Application 1.1.5* or *Pt 4, Ch 9, 1.1 Application 1.1.7*.

1.5.3 Manually operated doors without remote control in bulkheads referred to in *Pt 4, Ch 9, 1.4 Ship arrangement – Subdivision and transverse bulkheads 1.4.5* are permitted only in areas not accessible to passengers. They shall:

(a) remain closed at all times and be opened only temporarily to allow access;
(b) be fitted with suitable devices to enable them to be closed quickly and safely;
(c) display the following notice on both sides of the doors: ‘Close door immediately after passing through’.

1.5.4 Doors in bulkheads referred to in *Pt 4, Ch 9, 1.4 Ship arrangement – Subdivision and transverse bulkheads 1.4.5* that are open for long periods shall comply with the following requirements:

(a) They shall be capable of being closed from both sides of the bulkhead and from an easily accessible point above the bulkhead deck.
(b) After being closed by remote control the door shall be such that it can be opened again locally and closed safely. Closure shall not be impeded by carpeting, foot rails or other obstructions.

1.5.5 Doors of passenger rooms shall comply with the following requirements:

(a) with the exception of doors leading to connecting corridors, they shall be capable of opening outwards or be constructed as sliding doors.
(b) cabin doors shall be made in such a way that they can also be unlocked from the outside at any time.
(c) powered doors shall be able to be opened easily in the event of failure of the power supply.

1.5.6 Doors intended for use by persons with reduced mobility shall have a minimum clearance of 0,60 m between the inner edge of the doorframe on the side where the lock is located and the adjacent perpendicular wall.

1.5.7 Cold-storage room doors, even when locked, shall be capable of being opened from the inside.

1.6 Ship arrangement – Calculation of the maximum number of passengers

1.6.1 The maximum number of passengers that may be carried is to be assigned by the National Authorities in accordance with the regulations referred to in *Pt 4, Ch 9, 1.1 Application 1.1.5* and *Pt 4, Ch 9, 1.1 Application 1.1.7*.

1.7 Ship arrangement – Means of escape, corridors and escape routes

1.7.1 Rooms or groups of rooms designed or arranged for 30 or more passengers or including berths for 12 or more passengers shall have at least two exits. On day trip vessels one of these two exits can be replaced by two emergency exits.

1.7.2 For spaces below the freeboard deck, one of the exits may lead through a watertight bulkhead door in accordance with *Pt 4, Ch 9, 1.5 Ship arrangement – Watertight doors and doors 1.5.4*, leading into an adjacent compartment from which the upper deck can be reached directly. The other exit shall lead directly or, if permitted in accordance with *Pt 4, Ch 9, 1.7 Ship arrangement – Means of escape, corridors and escape routes 1.7.1* as an emergency exit into the open air or to the bulkhead deck. The foregoing is not applicable to exits of individual cabins.

1.7.3 Exits according to *Pt 4, Ch 9, 1.7 Ship arrangement – Means of escape, corridors and escape routes 1.7.1* and *Pt 4, Ch 9, 1.7 Ship arrangement – Means of escape, corridors and escape routes 1.7.2* shall be suitably arranged and shall have a

clear width of at least 0,80 m and a clear height of at least 2,00 m. For doors of passenger cabins and other small rooms, the clear width may be reduced to 0,70 m.

1.7.4 The width of exits of spaces and combined spaces intended for more than 80 passengers shall be at least 0,01 m per passenger.

1.7.5 Openings for emergency exits shall have a shortest side of at least 0,60 m or a minimum diameter of 0,70 m. Covers shall open in the direction of escape and be shall be marked on both sides as emergency exit.

1.7.6 Exits of rooms intended for use by persons with reduced mobility shall have a clear width of at least 0,90 m. Exits normally used for embarking and disembarking people with reduced mobility shall have a clear width of at least 1,50 m.

1.7.7 Connecting corridors shall have a clear width of at least 0,80 m. If they lead to rooms used by more than 80 passengers their width is to be at least 0,01 m per passenger. The clear height shall be not less than 2,00 m.

1.7.8 Connecting corridors intended for use by persons with reduced mobility shall have a clear width of 1,30 m.

1.7.9 Connecting corridors more than 1,50 m wide shall have handrails on either side.

1.7.10 Where a part of the vessel or a room intended for passengers is served by a single connecting corridor, the clear width of this corridor shall be at least 1,00 m.

1.7.11 Connecting corridors shall be free of steps and shall lead only to open decks, rooms or staircases. Dead ends in connecting corridors shall be not longer than 2 meters.

1.7.12 Stairways, exits and emergency exits shall be so disposed that, in the event of a fire in any given area, the other areas may be evacuated safely.

1.7.13 The route of escape routes shall to evacuation areas such as muster stations shall be as short as possible.

1.7.14 Escape routes shall not lead through engine rooms or galleys.

1.7.15 The fitting of rungs, ladders or similar is not allowed at any point along the escape routes.

1.7.16 Doors in escape routes shall be constructed in such a way as not to reduce the minimum width of the escape route required by*Pt 4, Ch 9, 1.7 Ship arrangement – Means of escape, corridors and escape routes 1.7.7* and *Pt 4, Ch 9, 1.7 Ship arrangement – Means of escape, corridors and escape routes 1.7.10*.

1.7.17 Escape routes and emergency exits shall be clearly marked. The signs shall be lit by the emergency lighting system.

1.8 Ship arrangement – Stairs

1.8.1 Stairs and their landings in the passenger areas shall comply with the following requirements:

(a) they shall be constructed in accordance with recognized standards such as the European standard EN 13056: 2000;
(b) they shall have a clear width of at least 0,80 m or, if they lead to connecting corridors or areas used by more than 80 passengers, at least 0,01 m per passenger;
(c) they shall have a clear width of at least 1,00 m if they provide the only means of access to a space intended for passengers;
(d) where there is not at least one staircase on each side of the vessel in the same zone, they shall lie in the safe area.

1.8.2 Stairs and their landings in the passenger areas intended for use by persons with reduced mobility shall comply with the following requirements:

(a) The gradient of the stairs shall not exceed 38°;
(b) The stairs shall have a clear width of at least 0,90 m;
(c) Spiral staircases are not allowed;
(d) The stairs shall not run in a direction transverse to the vessel;
(e) The handrails of the stairs shall extend approximately 0,30 m beyond the top and bottom of the stairs without restricting traffic routes;
(f) Handrails, front sides of at least the first and the last step as well as the floor coverings at the ends of the stairs shall be colour highlighted.

1.9 Ship arrangement – Bulwarks and openings

1.9.1 Parts of the deck intended for passengers, and which are not enclosed, shall comply with the following requirements:

(a) they shall be surrounded by a fixed bulwark or guard rail at least 1,00 m high or a railing according to the European standard EN 711: 1995, construction type PF, PG or PZ. Bulwarks and railings of decks intended for use by persons with reduced mobility shall be at least 1,10 m high.

1.9.2 Openings and provisions for embarking or disembarking and also openings for loading or unloading shall have a clear width of at least 1,00 m and shall be provided with safety arrangements.

1.9.3 Openings, normally used for the embarking or disembarking of persons with reduced mobility, shall have a clear width of at least 1,50 m.

1.10 Ship arrangement – Life saving appliances

1.10.1 Passenger ships are to be provided with life saving appliances as required by the competent national authorities, *see also Pt 4, Ch 9, 1.1 Application 1.1.5* and *Pt 4, Ch 9, 1.1 Application 1.1.7*.

1.11 Structural configuration

1.11.1 This Chapter provides for a basic structural configuration of a single deck hull with only small access openings, with superstructures or deckhouses over the greater part of the length of the ship and in view of stability requirements, mostly with a double bottom over the full breadth between peak tanks or double bottom wing tanks.

1.11.2 Transverse or longitudinal framing may be adopted. In large ships it is recommended to apply longitudinal framing in the bottom and strength deck. Alternatively transverse framing in bottom and strength deck, with additional longitudinal stiffening may be applied.

1.12 Class notation

1.12.1 Ships complying with the requirements of this Chapter will be eligible to be classed, for example '**A1 I.W.W. passenger ship (River Nile Service)**'.

1.12.2 The Regulations for classification and assignment of class notations are given in*Pt 1, Ch 2 Classification Regulations* to which reference should be made on the Survey request form. If application of stability, buoyancy and other safety criteria of National Authorities is requested and which are considered acceptable to LR, e.g. in view of a particular service area, a suitable notation in this respect will be entered in the *Register Book*.

1.12.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1 or for service extension the appropriate class notation will be assigned.

1.13 Information required

1.13.1 For the information required, *see Pt 3, Ch 1, 5 Information required*. In addition the following information, calculations and documentation are to be supplied:

(a) The maximum pressure head in service on tanks, also details of any tanks interconnected with side tanks, if fitted.

1.13.2 In addition to *Pt 4, Ch 9, 1.13 Information required 1.13.1*, the following aspects are to be satisfactory dealt with by the competent national authority, *see also Pt 4, Ch 9, 1.1 Application 1.1.5* and *Pt 4, Ch 9, 1.1 Application 1.1.7*, prior to the issue of the final certificates:

(a) Number of passengers to be carried with calculation of permissible maximum number of passengers.
(b) Intact stability calculations.
(c) Buoyancy and stability calculations for damaged conditions.
(d) Calculation of required minimum freeboard.
(e) Details of life-saving appliances.
(f) Details of fire protection, detection and extinction.

1.14 Symbols and definitions

1.14.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T, C_b or calculation of scantlings, as defined in *Pt 3, Ch 1, 6.1 Principal particulars*

k_L = *Table 2.1.1 Values of* K_L

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.3 Steel 1.3.3*

l = overall length of stiffening member, in metres, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point*

s = spacing of secondary stiffeners, i.e. frames, beams or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3.2 Geometric properties of section*

S = spacing or mean spacing of primary members, i.e. girders, transverses, webs, etc. in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3.2 Geometric properties of section*.

■ *Section 2* Materials and protection

2.1 Ceiling on single bottom

2.1.1 Where parts of the spaces below the upper deck with single bottom are intended to be used for storage purposes, efficient ceiling based on the actual loading is to be fitted.

■ *Section 3* Longitudinal strength

3.1 General

3.1.1 For the assessment of the required longitudinal strength which is to be maintained over the midship region, design bending moments are to be calculated. The design bending moments, sagging and hogging, are the maximum moments occurring when the ship is in any condition indicated in *Pt 4, Ch 9, 3.1 General 3.1.5* and are to be calculated and verified for ships of a length, L, of more than 65 m and for all ships of unusual type.

3.1.2 The design bending moments are to be determined by direct calculation.

3.1.3 For ships with machinery aft, as a value for assessment of required midship section modulus, the bending moment may be taken as:

$0,044\,(1 - 0,86C_b)\,L^2\,B\,T$ tonne-f m, (hogging)

where

L, B, T and C_b are as defined in *Pt 4, Ch 9, 1.14 Symbols and definitions 1.14.1*
but this value is to be verified by direct calculation for ships having a length, L, of 65 m and above.

3.1.4 For maximum permissible stresses, *see Pt 3, Ch 4, 6 Hull bending strength* .

3.1.5 The following loading conditions for determination of design bending moments are to be covered:

(a) Departure condition:

Ship completely equipped, fresh water, fuel and lubricating oil tanks full, the maximum allowed number of passengers, crew and stores on board and ballast tanks are to be considered as either empty or full in accordance with the actual condition.

(b) Arrival condition:

Ship completely equipped, fresh water, fuel and lubricating oil tanks 95 per cent empty and ballast tanks are to be considered as either empty or full in accordance with the actual condition.

(c) Any condition of the ship giving higher values of bending moments during the voyage.

3.1.6 Where an effective superstructure is fitted (*see Pt 3, Ch 3, 3.4 Calculation of hull section modulus 3.4.2*), it may be included in calculating the hull section modulus in way. Similarly a deckhouse may be included in calculating the hull section modulus in way, provided the longitudinal bulkheads are at least 0,75*B* apart, efficiently constructed, well supported, and having a length of at least 0,2*L* or 10 m whichever is the greater and situated within the midship region.

Section 4
Shell envelope plating

4.1 General

4.1.1 This Section covers the requirements for the shell envelope plating, *viz*., keel, bottom, bilge and side shell plating and sheerstrake plating.

4.1.2 The thickness of the shell envelope plating is to be not less than required in *Table 9.4.1 Shell envelope plating*, but for ships over 65 m in length the thickness of the bottom plating may require to be increased to meet the requirements of *Pt 4, Ch 9, 3 Longitudinal strength*.

Table 9.4.1 Shell envelope plating

Item and parameter		Requirements
(1)	Plate keel	
	Breadth	The greater of:
		0,1*B* m
		0,75 m
	Thickness	As bottom plating t_b
		When there is a rise of floor, the thickness is to be increased by 1 mm
(2)	Bottom plating	The greater of:
	Thickness	$t_b = (5,6 + 0,054L)\sqrt{ks}$ mm
		$t_b = 10s$ mm
(3)	Bilge plating	
	Thickness	$t = t_b + 2$ mm
(4)	Bilge chine bars	
	(a) Round bars	
	Diameter	$3t_b$ mm, but not less than 30 mm
	(b) Square bars	
	Side	$3t_b$ mm, but not less than 30 mm
	(c) Angle bars	
	Flange thickness	$t = 2t_b$ mm

(5)	Side shell plating Thickness	The greater of: $t_b = (5,6 + 0,054L)\sqrt{ks}$ mm t_b = 10s mm
(6)	Sheerstrake (only to be fitted in absence of efficient steel fender around the ship at deck height) Minimum width Thickness	 W_{sh} = 0,1D m t = side shell thickness as required in (5) + 5 mm
Symbols		
L, B, D, S, s, k and t are as defined in *Pt 4, Ch 9, 1.14 Symbols and definitions 1.14.1* t_b = thickness of bottom plating, in mm C_1 = $1 + 3\left(\frac{s}{S}\right)^2$, where $\frac{s}{S}$ is the ratio of the unstiffened bottom panel under consideration		

4.1.3 For requirements in respect of structural details, *see Pt 3, Ch 10 Welding and Structural Details*.

4.2 Keel

4.2.1 The breadth and thickness of the keel plate is to comply with the requirements of *Table 9.4.1 Shell envelope plating* and is to be maintained over the full length of the ship.

4.3 Bottom plating

4.3.1 The thickness of bottom plating is to comply with the requirements of *Table 9.4.1 Shell envelope plating* and is to be maintained over the midship region and may be tapered to the end thickness in the forward and aft region (*see Pt 3, Ch 5 Fore End and Aft End Structure*), according to the requirements for taper given in *Pt 3, Ch 3, 2.5 Principles for taper*.

4.4 Bilge plating

4.4.1 The thickness of the bilge plating is to be maintained from amidships to well beyond the forward and aft shoulder of the bilge, but at least over the midship region. For definition of shoulder, *see Pt 3, Ch 5, 2.4 Shell plating 2.4.2*.

4.4.2 The bilge radius is to be at least 10 times the thickness of the bilge plating and the bilge strake is to extend at least 100 mm on either side of the radius.

4.4.3 Square bilges, constructed by solid round, square or externally fitted angle bars (*see Figure 9.4.1 Square bilge arrangements*), are to comply with *Table 9.4.1 Shell envelope plating*. The bottom plating and side shell plating adjacent to the round, square or angle bars need not be increased above that of the bottom plating or side shell plating in way.

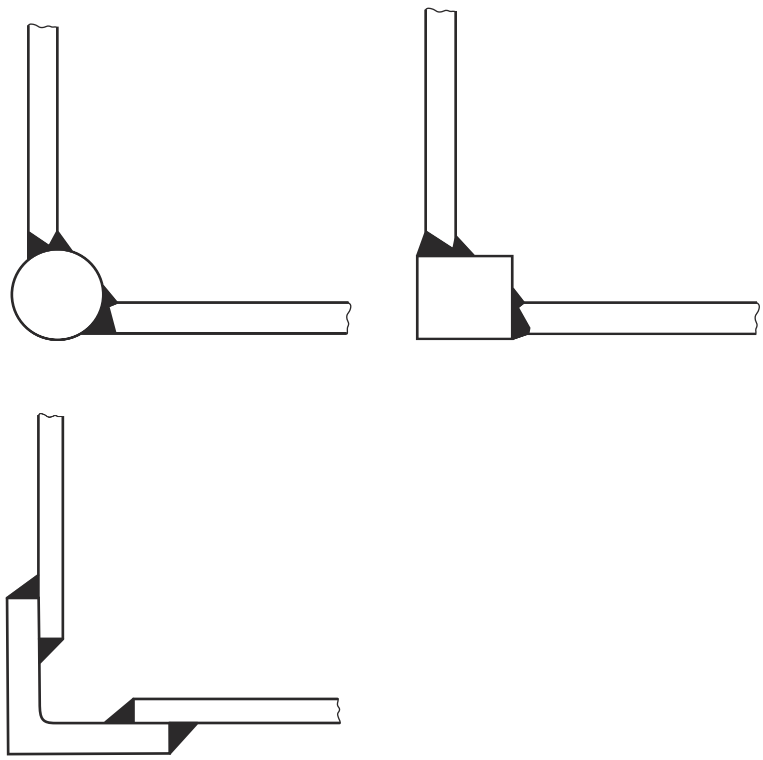


Figure 9.4.1 Square bilge arrangements

4.5 Side shell plating

4.5.1 The thickness of the side shell plating is to comply with the requirements of *Table 9.4.1 Shell envelope plating*, which is to be maintained over 0,5*L* amidships and may be tapered to the end thickness in the forward and aft region (*see Pt 3, Ch 5 Fore End and Aft End Structure*), according to the requirements for taper given in *Pt 3, Ch 3, 2.5 Principles for taper*.

4.6 Sheerstrake

4.6.1 The width and the thickness of the sheerstrake is to comply with the requirements of *Table 9.4.1 Shell envelope plating*.

4.7 Shell openings

4.7.1 Openings in the shell plating are to have well rounded corners, compensation is generally only required for openings having a width greater than 250 mm. The edges of openings in the shell for side scuttles and windows are to be reinforced on the inside by angle bars of at least 75 mm in height to which the frames of the side scuttles and windows are to be fastened and thus protected. Compensation for the shell plating cut out is only required in the case of large windows. Openings in way of or near the bilge radius are to be circular or elliptical.

■ *Section 5* Deck plating

5.1 General

5.1.1 This Section covers the requirements for the deck plating, which is to be maintained over the midship region and may be tapered to the end thickness in the forward and aft end region (*see Pt 3, Ch 5 Fore End and Aft End Structure*), according to the requirements for taper given in *Pt 3, Ch 3, 2.5 Principles for taper*.

5.1.2 Where openings are made in the deck plating for access or where a deckhouse is sunk into the deck, the deck plating in way is to be increased in thickness to compensate for the material cut out. No compensation need be fitted if the loss of sectional area has already been taken into account when calculating the actual midship hull section modulus.

5.1.3 Circular openings in the deck plating of a diameter of 150 mm or less need not be compensated, provided they are situated well clear of other openings and the area cut out transversely over the deck does not exceed three per cent of the total cross-sectional area.

5.1.4 Plate panels, in which openings are cut, may have to be adequately stiffened at the edges of the openings.

5.2 Thickness of deck plating

5.2.1 The deck plating thickness is to be not less than as required in *Table 9.5.1 Deck plating*, but for ships of a length, *L*, of 65 m and over the deck plating may require to be increased to meet the requirements of *Pt 4, Ch 9, 3 Longitudinal strength*.

Table 9.5.1 Deck plating

Item and parameter	Requirements
Deck plating	
Thickness	The greater of: $t = (5,6 + 0,039L)\sqrt{ks}$ mm t = 10s mm
For symbols *see Table 9.5.2 Deck plating within superstructures and deckhouses*	

Table 9.5.2 Deck plating within superstructures and deckhouses

Item and parameter	Requirements
Deck plating	
Thickness	t = 9s mm
Symbols applying to *Table 9.5.1 Deck plating* and *Table 9.5.2 Deck plating within superstructures and deckhouses*	
L, *B*, *D*, *t* and *s* = as defined in*Pt 4, Ch 9, 1.14 Symbols and definitions 1.14.1* a_1 = total area of deck longitudinals, in cm^2 *M* = the greater of *MS* and *MH* *MH* = maximum design hogging bending moment, in tm, *see Pt 3, Ch 4 Longitudinal Strength* *MS* = maximum design sagging bending moment, in tm, see *Pt 3, Ch 4 Longitudinal Strength*	

5.2.2 The thickness of deck plating within superstructures or deckhouses having a length of at least 0,2*L* or 10 m whichever is the greater and situated within the midship region is to comply with the requirements of *Table 9.5.2 Deck plating within superstructures and deckhouses*, but the exposed deck plating at the sides of the deckhouse is to be carried into the deckhouse over a breadth of at least 75 per cent of the frame spacing in way. The exposed deck plating is to be extended into the superstructure or deckhouse at the ends over two frame spaces.

Section 6
Single bottom structure

6.1 General

6.1.1 Requirements are given in this Section for a transversely framed or a longitudinally framed single bottom.

6.1.2 The bottom structure of ships of a length, L, less than 25 m is to comply with the requirements of *Pt 3, Ch 5 Fore End and Aft End Structure* so far as applicable.

6.1.3 The scantlings of structural members of the single bottom of ships having a length of 25 m and over, are to comply with the requirements of *Table 9.6.1 Transversely and longitudinally framed single bottom*.

Table 9.6.1 Transversely and longitudinally framed single bottom

Item	Parameter	Requirements
Longitudinal and transverse framing system		
Centreline girder	Web depth	The lesser of:
		d_w = 40B mm
		d_w = 50l_f mm
Centreline girder and	Web and face plate thickness	$t = (0{,}01d_w + 2)\sqrt{k}$ mm
side girders	Width of face plate	w = 140s mm
Transverse framing system		
Floors	Web depth at centreline	The lesser of
		d_f = 40B mm
		d_f = 50l_f mm
	Web thickness	$t = (0{,}01d_w + 2)\sqrt{k}$ mm
	Face plate thickness	$t = \geq t_{web}$ mm
	Face plate width	The greater of:
		w = 30l_f mm
		w = 60 mm
	Minimum required modulus	$Z = 6{,}6kB^2D_1\ s$ cm^3
Longitudinal framing system		
Bottom transverses	Web thickness	$t = (0{,}01d_w + 3)\sqrt{k}$ mm
	Face plate width	The greater of:
		w = 30l_f mm
		w = 60 mm
	Modulus	$Z = 6{,}6kB^2D_1\ S$ cm^3
Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)\ D_1\ ksl_e^2$ cm^3
	Inertia	$I = \frac{2,3}{k} l_e\ Z$ cm^4

Symbols applying to *Table 9.6.1 Transversely and longitudinally framed single bottom* and *Table 9.7.1 Transversely and longitudinally framed double bottom*
L, B, D, T, s, S, t, l, k, Z and l_e are as defined in *Pt 4, Ch 9, 1.14 Symbols and definitions 1.14.1* d_f = depth of floor or bottom transverse at centreline, in mm d_w = depth of girder, in mm l_b = the width of the double bottom, in metres, and is normally the breadth of the ship. If longitudinal bulkheads or equivalent supports are provided, an equivalent breadth may be used, but this is to be taken not less than 0,8B l_f = span of floor or transverses which is normally the breadth of the ship measured on top of the floor under consideration, in metres. If longitudinal bulkheads or equivalent floor supports are provided, an equivalent breadth may be used, but this should be taken as not less than 0,4B t_1 = thickness of inner bottom plating or bottom plating whichever is the lesser, in mm w = width of face plate or member, in mm D_1 = D, but need not be taken greater than T + 0,4 m or Zone 3, T + 0,7 m for Zone 2, T + 1,0 m for Zone 1 L_1 = L but is to be taken as not less than 65 m

6.1.4 The bottom structure of ships of a length, L, longer than 110 m is to have the double bottom structure according to *Pt 4, Ch 9, 7.1 General 7.1.7*.

6.2 Girders

6.2.1 A centreline girder is required in ships with a breadth, B, of more than 6 m.

6.2.2 A side girder is to be fitted on each side of the centreline in ships with a transversely framed bottom and a breadth, B, or more than 12 m.

6.2.3 Where no centreline girder is fitted, adequate support on the centreline must be provided for docking purposes.

6.3 Floors and transverses

6.3.1 Plate floors are to be fitted at every frame.

6.3.2 Transverses are generally to be fitted at a spacing of not more than 3,5 m. However special consideration will be given to proposals for a greater spacing.

6.3.3 In ships having considerable rise of floor the tops of the floors and the transverses are to be made approximately parallel to the rise of floor.

6.3.4 Floors may be cut at the centreline, with the centreline girder web plate continuous, provided the transverse strength of the floor is maintained.

6.3.5 Floors are to be provided with drain holes, sufficient in number and size.

6.3.6 The depth of the transverses is generally to be not less than twice the depth of the slot for the longitudinals.

6.3.7 Longitudinals are generally to be carried through watertight floors and transverse bulkheads. If they stop at the watertight floors and transverse bulkheads, brackets are to be fitted inter-connecting the longitudinals, *see Pt 3, Ch 10, 3.3 Basis for calculation of bracket connections 3.3.1.(c)*.

6.3.8 Scallops in longitudinals may not be fitted in way of end connections, crossings with transverses or tripping brackets.

■ Section 7
Double bottom structure

7.1 General

7.1.1 Requirements are given in this Section for a transversely framed or a longitudinally framed double bottom.

7.1.2 The scantlings of structural members of the double bottom, transversely or longitudinally framed, are to comply with the requirements of *Table 9.7.1 Transversely and longitudinally framed double bottom*.

Table 9.7.1 Transversely and longitudinally framed double bottom

Item	Parameter	Requirements
Longitudinal and transverse framing systems		
Double bottom height at centreline	Minimum depth	The greater of: d_f= 40B mm $d_f = \frac{12D_1 \times I_b^2}{t_i}$ mm
Centreline and side girders	Web thickness	$t = (0{,}01d_f + 2)\sqrt{k}$ mm
Inner bottom plating	Thickness for dry spaces	t = 10s mm
	Thickness for tanks	The greater of: t = 12s mm t = 5,5 mm
Transverse framing system		
Plate floors and brackets of bracket floors	Web thickness	The greater of: $t = (0{,}008d_f + 1{,}5)\sqrt{k}$ mm t = 5,5 mm
Bracket floors:		
bottom frames	Modulus	$Z = 6{,}6ks\text{-}D_1 l_e\ 2^2$ cm^3
reverse frames	Modulus	$Z = 5{,}6ksD_1 l_e^2$
Longitudinal framing system		
Plate floors	Web thickness	$t = (0{,}009d_f + 1{,}5)\sqrt{k}$ mm
Double bottom longitudinals	Modulus	$Z = 6ks\ D_1\text{-}l_e^{\ 2}$ cm^3
For Symbols *see Table 9.6.1 Transversely and longitudinally framed single bottom*		

7.1.3 The depth of the double bottom is to comply with the requirements of *Table 9.7.1 Transversely and longitudinally framed double bottom*, but it is recommended that the double bottom be accessible for inspection and surveys.

7.1.4 Provision is to be made for free passage of air and water from all parts of the double bottom compartments to the air pipes and suctions, account being taken of the pumping rates required. Where access openings are cut in the floors and girders, the height of openings should not, in general, exceed 50 per cent of the double bottom depth. Openings in way of ends of floors and girders are to be avoided.

7.1.5 Where the double bottom is not continuous over the full breadth of the ship (for example at the centreline to form a pipe recess), the transverse strength of the bottom structure is to be maintained and is to comply with the minimum requirements of this Section.

7.1.6 Where a margin plate is proposed to form a bilge, the thickness of the margin plate is to be 1 mm more than required for the inner bottom plating.

7.1.7 Passenger ships of a length, *L*, longer than 110 m are to:

(a) have a double bottom with a height of at least 600 mm and subdivision to ensure that, in the event of flooding of any two adjacent watertight compartments, the vessel does not immerse lower than the margin line and a residual safety clearance of 100 mm remains, or have a double bottom with a height of at least 600 mm and a double hull with a distance of at least 800 mm between the side wall of the vessel and the longitudinal bulkhead;
(b) be fitted with a multi-propeller propulsion system with at least two independent engines of equal power and a bow thruster system which can be operated from the wheelhouse and which operates longitudinally as well as transversely.

7.1.8 A double bottom is required according to *Pt 4, Ch 9, 7.1 General 7.1.7*. The double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

7.2 Girders

7.2.1 A centreline girder is required in ships with a breadth, *B*, of more than 6 m. A side girder is generally to be fitted on each side of the centreline in ships with a transversely framed bottom and a breadth, *B*, of more than 12 m. Proposals to omit the centreline girder and/or side girders will be specially considered, but adequate support must be provided on the centreline for docking purposes.

7.3 Floors

7.3.1 In transversely framed double bottoms, plate floors are to be fitted at every frame. Alternatively, bracket floors may be fitted (*see Pt 3, Ch 5, 3.5 Double bottoms*), provided plate floors are fitted, spaced not more than 2,5 m apart.

7.3.2 In longitudinally framed double bottoms, floors are to be fitted at a spacing not exceeding 3,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. In between the floors, brackets are to be fitted in the double bottom in line with the transverse side frames, connected to the tank top and shell plating and extending to the nearest bottom and inner bottom longitudinal. Midway between floors, brackets are to be fitted on either side of the centreline extending to the nearest bottom and inner bottom longitudinals. Free edges of the brackets are to be suitably stiffened.

7.3.3 Plate floors are also to be arranged under bulkheads and in line with web frames fitted in the side structure.

7.4 Inner bottom plating

7.4.1 The thickness of the inner bottom plating is to comply with the requirements of *Table 9.7.1 Transversely and longitudinally framed double bottom*.

7.5 Bottom and inner bottom longitudinals

7.5.1 The scantlings of bottom and inner bottom longitudinals are to comply with the requirements of *Table 9.6.1 Transversely and longitudinally framed single bottom* and *Table 9.7.1 Transversely and longitudinally framed double bottom* and are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*.

Section 8
Shell envelope framing

8.1 General

8.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is not adopted over the full length of the ship, it is to be efficiently scarfed into the transverse framing system.

8.1.2 The scantlings of side frames in the midship region which are based on end connections in accordance with *Pt 3, Ch 10, 3 Secondary member end connections*, are to comply with the requirements given in *Table 9.8.1 Shell side frames and longitudinals*. Where brackets having arm lengths differing from the standard are fitted, the frame modulus is to be corrected in accordance with *Pt 3, Ch 10, 3.7 Correction of stiffening member modulus in relation to end connections*.

Table 9.8.1 Shell side frames and longitudinals

Location	Modulus
Clear of tanks	
Frames	$Z_F = 1{,}2D_1\, ks(2{,}5H^2 + 0{,}03B^2 + 6)$ cm^3
Side shell longitudinals	$Z_{SL} = 6ksl_e^2\, h_5 + 4$ cm^3
Side transverses longitudinal framing system	*See Pt 4, Ch 9, 8.3 Longitudinal shell framing 8.3.1*
Side frames of combination system in way of bottom/deck transverse	$Z = 2Z_F$ cm^3
In way of O.F. or water tanks	The greater of:
Frames	$Z_{TF} = Z_F$
	$Z_{TF} = 4{,}3ksl_e^2 h_4 + 4$ cm^3
Side shell longitudinals	The greater of:
	$Z_{TSL} = Z_{SL}$
	$Z_{TSL} = 4{,}3ksl_e^2 h_4 + 4$ cm^3
Side transverses longitudinal framing system	*See Pt 4, Ch 9, 8.3 Longitudinal shell framing 8.3.1*
Side frames of combination system in way of bottom/deck transverse	$Z = 2Z_{TF}$ cm^3

Symbols
L, *B*, *s*, *k* and *Z* as defined in *Pt 4, Ch 9, 1.14 Symbols and definitions 1.14.1* l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point* D_1 = *D*, but need not be taken greater than *T* + 0,4 m for Zone 3, *T* + 0,7 m for Zone 2, *T* + 1,0 m for Zone 1 *H* = vertical framing depth, in metres, from the top edge of floor or tank top, to the deck at side as shown in *Figure 5.4.1 Framing depth* in Pt 3, Ch 5 h_4 = load head, in metres, measured vertically from the middle of the effective length to a point 1 metre above the top of the tank, or to the top of the overflow, whichever is the greater h_5 = load head, in metres, measured vertically from the middle of the effective length to the deck at side or to a point *T* + 0,4 m for Zone 3, *T* + 0,7 m for Zone 2, *T* + 1,0 m for Zone 1 above baseline, whichever is the lesser, but to be taken as not less than 1,5 m

8.2 Transverse shell framing

8.2.1 When the side frames are supported by an effective system of stringers and web frames the Rule section modulus of the frames (ignoring the stringers) may be reduced by 30 per cent.

8.2.2 Where a combination framing system is adopted (shell transverse and bottom deck longitudinal framing) a transverse ring system is to be arranged in way of the supports of the longitudinal stiffening members. The section modulus of the side frames in way of the bottom and deck transverse is to be increased by 100 per cent, and the end connections are to comply with the requirements of *Pt 3, Ch 10, 3 Secondary member end connections*. Brackets at the top and bottom of the side frames are to be connected to the respective adjacent deck and bottom longitudinals. When the frames are carried through the bilge radius, they may be directly connected to the outboard longitudinal.

8.3 Longitudinal shell framing

8.3.1 Longitudinal stiffening members are to be supported by shell transverses which are to comply with the requirements of *Table 9.8.1 Shell side frames and longitudinals*. End brackets may be omitted if the modulus of the shell transverse at the intersection with the bottom transverse is equal to that of the bottom transverse, and at the intersection with the deck transverse is at least equal to that of the deck transverse. The face bar of the side transverse is to be welded to the face bar of the bottom and deck transverse. The web plate of the bottom and deck transverse is to be stiffened in line with the face bar of the side transverse.

8.3.2 The shell transverses are to form a ring system with bottom and deck transverses.

■ Section 9
Deck structure

9.1 Deck supporting structure

9.1.1 The transverse and longitudinal deck supporting structure is to comply with the requirements of *Table 9.9.1 Deck supporting structure*.

Table 9.9.1 Deck supporting structure

<table>
<tr><td colspan="2">Item</td><td colspan="2">Modulus</td></tr>
<tr><td colspan="2">Transverse deck beams</td><td colspan="2">$Z_{TD} = 4{,}3ksl_e^2h_1 + 4$ cm^3</td></tr>
<tr><td colspan="2">Transverse beams in way of crown of tank</td><td colspan="2">$Z_{TDCT} = 4{,}3ksl_e^2h_2 + 4$ cm^3</td></tr>
<tr><td colspan="2">Deck longitudinals</td><td colspan="2">$Z_{DL} = 4{,}3ksl_e^2h_1 + 4$ cm^3</td></tr>
<tr><td colspan="2">Deck longitudinals in way of crown of tank</td><td colspan="2">$Z_{DLCT} = 4{,}3ksl_e^2h_2 + 4$ cm^3</td></tr>
<tr><td>Item</td><td colspan="2">Parameter</td><td>Requirements</td></tr>
<tr><td>Girders and transverses in dry spaces

Pillars in dry spaces, see Note</td><td colspan="2">Modulus

Inertia</td><td>$Z = 4{,}75kh_1Sl_e^2$ cm^3

$I = \frac{2,3}{k} l_e Z$ cm^4</td></tr>
<tr><td></td><td colspan="2">Cross sectional area of all types of pillars</td><td>$A_r = \frac{P}{1,26 - 4,2\frac{l}{r}}$ cm^2</td></tr>
<tr><td></td><td colspan="2">Minimum wall thickness of hollow pillars</td><td>The greater of:</td></tr>
<tr><td></td><td colspan="2"></td><td>(a) $t = 0{,}033d_p$ mm for tubular pillars</td></tr>
<tr><td></td><td colspan="2"></td><td>$t = 0{,}056b$ mm for square pillars</td></tr>
<tr><td></td><td colspan="2"></td><td>(b) $t = 5$ mm</td></tr>
<tr><td colspan="4">Symbols</td></tr>
</table>

L, s, S, Z, l, k and t as defined in*Pt 4, Ch 9, 1.14 Symbols and definitions 1.14.1* b = breadth of side of a hollow rectangular pillar, in mm d_ρ = mean diameter of tubular pillars, in mm h_1 = head, in metres, as defined in *Pt 3, Ch 3, 4 Design loading* h_2 = load head, in metres, measured vertically from the middle of effective length to a point 1 m above the top of tank, or to top of the overflow, whichever is the greater l = overall length of pillar, in metres l_e = effective length of stiffening member, in metres, but is to be taken not less than 3 m r = least radius of gyration of pillar cross-section, in mm, and may be taken as: $r = 10\sqrt{\frac{I_\rho}{A_\rho}}$ A_ρ = cross-sectional area of pillar, in cm^2 I_ρ = least moment of inertia of cross-section, in cm^4 P = load supported by the pillar, in tonne-f
Note For deck supporting structure in tanks, *see also Pt 3, Ch 7 Bulkheads*.

9.1.2 Deck girders and transverses may be fitted in conjunction with load bearing bulkheads or pillars for support of deck beams or deck longitudinals.

9.1.3 Load bearing bulkheads or webs are to be fitted below the deck in line with web stiffeners supporting erection bulkheads.

9.1.4 Effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Tripping brackets or equivalent are to be fitted to the transverse or girder web plates in way of pillars. Where eccentric loads are to be supported, the pillars are to be strengthened for the additional bending moment imposed upon them.

■ *Section 10* **Erections**

10.1 General

10.1.1 Erections are to be constructed, in general, according to the requirements of *Pt 3, Ch 8 Superstructures, Deck-houses and Bulwarks*.

10.1.2 Where an erection is fitted complying with *Pt 4, Ch 9, 3.1 General 3.1.6* the thickness of the deck plating is to comply with the requirements of *Table 9.10.1 Deck plating of effective superstructures and deckhouses*, but on ships having a length of 65 m and over the thickness may require to be increased to meet the requirements of *Pt 4, Ch 9, 3 Longitudinal strength*.

Table 9.10.1 Deck plating of effective superstructures and deckhouses

Item and parameter	Required
Deck plating Thickness	$t = (5,6 + 0,030L)\sqrt{s}$ mm

Symbols
L, *t* and *s* as defined in *Pt 4, Ch 9, 1.14 Symbols and definitions 1.14.1*

10.1.3 The side plating of effective erections is to be well stiffened at ends and efficient scarfing into the main structure is to be arranged.

■ *Section 11* Direct calculation procedures

11.1 General

11.1.1 This Section contains guidance for direct calculations, information concerning maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

11.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads, are to be submitted for approval together with the calculation.

11.2 Permissible stresses

11.2.1 In addition to the permissible stresses given in *Pt 3, Ch 4, 6 Hull bending strength* the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 9.11.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2*.

(b) For structural members not included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in *Table 9.11.2 Maximum permissible stresses in local members, in N/mm^2*.

Table 9.11.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2

Item	Local bending stress, σ_b	Combined bending, σ_c *See* Note 1	Shear stress, τ	Equivalent stress, σ_e *See* Note 2
Bottom girders	0,46σ_L	0,75σ_L	0,35σ_L	0,80σ_L
Bottom longitudinals Inner bottom longitudinals Side shell longitudinals	0,58σ_L	0,75σ_L	0,35σ_L	0,80σ_L
Symbols				
Where $\sigma_L = 235/k_L$ **Note** 1. The combined stress σ_c is the sum of the stresses due to longitudinal bending and local loading. **Note** 2. The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$				

Table 9.11.2 Maximum permissible stresses in local members, in N/mm²

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *See* Note
Floors, non-continuous girders, bottom and deck, deck transverses, bottom transverses	$0,53\sigma_o$	$0,35\sigma_o$	$0,75\sigma_o$
Frames	$0,48\sigma_o$	$0,35\sigma_o$	$0,73\sigma_o$
Deck beams	$0,58\sigma_o$	$0,35\sigma_o$	$0,79\sigma_o$
Note The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$			

11.3 Structural requirements

11.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

11.3.2 In addition to the maximum permissible stresses given in *Pt 4, Ch 9, 11.2 Permissible stresses* the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see Pt 3, Ch 5, 2 Hull envelope plating*.

(b) The thickness of the bilge plating amidships is to be 2 mm more than the bottom plating in way.

(c) The minimum thickness of the deck plating is to be not less than required by *Table 5.2.2 Deck plating forward and aft*(1) in Pt 3, Ch 5.

(d) Depending on the level of compressive stresses, additional buckling calculations may be required.

Contents

Section

■ Scope

The Chapters in this Part cover the construction and installation of main propulsion and auxiliary machinery systems, together with their associated equipment, boilers, pressure vessels and pumping and piping arrangements fitted in classed ships.

■ *Section 1* General

1.1 Machinery to be constructed under survey

1.1.1 In ships built under Special Survey, all important units of equipment are to be surveyed at the manufacturer's works. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:

- Main propulsion engines, including their associated gearing, flexible couplings, scavenge blowers and superchargers.
- Boilers intended for heating of cargo and/or domestic purposes, having working pressures exceeding 0,34 N/mm^2 and having heating surfaces greater than 4,65 m^2.
- Auxiliary engines of 110 kW and over, which are the source of power for services essential for safety or for the operation of the ship.
- Steering machinery.
- Athwart ship thrust units and Azimuth thrusters of 110 kW and over, their prime movers and control mechanisms.
- All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g. air, water and lubricating oil coolers.
- Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery.
- Any other unfired pressure vessels for which plans are required to be submitted as detailed in *Pt 5, Ch 9, 1.6 Plans*.
- All pumps essential for safety of the ship, e.g. fire and bilge pumps.
- Valves and other components intended for the installation in pressure piping systems having working pressures exceeding 7 bar.
- Alarm and control equipment as detailed in *Pt 6, Ch 1 Control Engineering Systems*.
- Electrical equipment as detailed in *Pt 6, Ch 2 Electrical Installations*.

1.2 Survey for classification

1.2.1 The Surveyor is to examine and test the materials and examine the workmanship from the commencement of work until the final test of the machinery under full working conditions. Any defects, etc. are to be indicated as early as possible. On completion, the Surveyor will submit a report and if this is found to be satisfactory by the Committee, a certificate will be granted, and an appropriate notation assigned in accordance with *Pt 1, Ch 2 Classification Regulations*.

1.3 Alternative system of inspection

1.3.1 Where items of machinery are manufactured as individual or series produced units, the Committee will be prepared to give consideration to the adoption of a survey procedure based on quality assurance concepts utilizing regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

1.3.2 In order to obtain approval, the requirements of *Pt 5, Ch 1, 7 Quality Assurance Scheme for Machinery* are to be complied with.

1.3.3 Where it is proposed to install engines and gears not surveyed at the manufacturer's works, but of a recognized and approved standard type, these items are to be tested under full working conditions after fitting on board. Installation of such machinery is to be carried out in accordance with the relevant requirements of the Rules. This survey will entitle the machinery to the special notation in accordance with *Pt 1, Ch 2 Classification Regulations*.

1.4 Deviations from the Rules

1.4.1 Any proposal to deviate from the requirements of the Rules will be specially considered.

■ *Section 2*
Plans and particulars

2.1 Plans

2.1.1 Before the work is commenced, plans in triplicate of all machinery items, as detailed in the Chapters giving the requirements for individual systems, are to be submitted for consideration. The particulars of the machinery, including power ratings and design calculations, where applicable, necessary to verify the design, are also to be submitted. Any subsequent modifications are subject to approval before being put into operation. It is not necessary for plans and particulars to be submitted for each ship, provided the basic plans for the machinery installation have previously been approved. Any alterations to basic design, materials or manufacturing procedure are to be re-submitted for consideration.

2.2 Materials

2.2.1 The materials used in the construction are to be manufactured and tested in accordance with the requirements of Lloyd's Register's (hereinafter referred to as LR) *Rules for the Manufacture, Testing and Certification of Materials, July 2022* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and satisfy such tests as may be considered necessary.

2.2.2 Materials used in the construction of machinery and its installation are not to contain asbestos.

2.3 Welding

2.3.1 Welding consumables, plant and equipment are to be in accordance with the requirements specified in *Ch 13, 1.8 Welding equipment and welding consumables* of the Rules for Materials.

2.3.2 Welding procedures and welder qualifications are to be tested and qualified in accordance with the requirements specified in *Ch 12 Welding Qualifications* of the Rules for Materials.

2.3.3 Production weld tests are to be carried out where specified in the subsequent Chapters of these Rules.

2.3.4 All finished welds are to be subjected to non-destructive examination in accordance with the requirements specified in *Ch 13, 2.12 Non-destructive examination of steel welds* of the Rules for Materials and or the requirements specified in the subsequent Chapters of these Rules.

Section 3
Operating conditions

3.1 Availability for operation

3.1.1 The design and arrangements are to be such that the machinery can be started and controlled on board ship, without external aid, so that the operating conditions can be maintained under all circumstances.

3.1.2 Machinery is to be capable of operating at defined power ratings with a range of fuel grades specified by the engine, boiler or machinery manufacturer and agreed by the Owner/Operator.

3.1.3 Machinery is to be capable of operating satisfactorily in accordance with the manufacturer's stated operating conditions within an operational profile specified for the ship by the Owner/Operator and agreed by the manufacturer/system designer.

3.2 Fuel

3.2.1 The flash point (closed cup test) of fuel oil is to be not less than 55°C, unless specially approved.

3.2.2 Fuels with flash points lower than 55°C, but not less than 43°C, unless specially approved, may be used in ships intended for service restricted to certain geographical limits, where it can be ensured that the temperature of the machinery spaces will always be 10°C below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered.

3.2.3 The use of fuel having a lower flash point than specified in *Pt 5, Ch 1, 3.2 Fuel 3.2.1* and *Pt 5, Ch 1, 3.2 Fuel 3.2.2*, as applicable, may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

3.3 Power ratings

3.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute to be used in service.

3.4 Definitions

3.4.1 Main propulsion engines are defined as those which drive main propelling machinery directly or indirectly through mechanical shafting and which may also drive electrical generators to provide power for auxiliary services. Auxiliary engines are defined as those coupled to electrical generators which provide power for auxiliary services, for electrical main propulsion motors or a combination of both.

3.4.2 Units and formulae included in the Rules, are shown in SI units.

3.4.3 Pressure gauges may be calibrated in bar, where 1 bar = 0,1 N/mm^2.

3.5 Temperature conditions

3.5.1 The rating of main and essential auxiliary machinery is to be suitable for the temperature conditions associated with the geographical limits of the proposed service.

3.6 Power conditions for generator sets

3.6.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see Pt 6, Ch 2 Electrical Installations*.

3.6.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in *Pt 5, Ch 1, 3.5 Temperature conditions*. Alternatively, where it is not practicable to test the engine/generator set as a

unit, type tests (e.g. against a brake) representing a particular size and range of engines may be accepted. With engines, any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

3.7 Astern power

3.7.1 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

3.8 Bearings

3.8.1 Roller element bearings are to have an L10 design life of at least 30 000 hours, based upon the design operating conditions. An L10 design life of less than 30 000 hours would be accepted, provided it is proposed in conjunction with the manufacturer's design/maintenance manual.

■ *Section 4* Machinery room arrangements

4.1 Accessibility

4.1.1 Accessibility, for attendance and maintenance purposes, is to be provided for machinery plants.

4.2 Machinery fastenings

4.2.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the ship’s structure to the satisfaction of the Surveyor.

4.2.2 Where the machinery is installed on resilient mountings, linear vibration (steady state and transient) is not to exceed the limiting values agreed with the manufacturer of the machinery or those of the resilient mountings. Misalignment arising from such vibration is not to impose excessive loading on machinery components within the system.

4.2.3 The Shipbuilder is to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

4.2.4 Anti-collision chocks are to be fitted together with positive means to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

4.3 Ventilation

4.3.1 All spaces, including engine and cargo pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions.

4.3.2 Machinery spaces with a total installed power rating exceeding 375 kW or containing oil fired equipment shall be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, a sufficient supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery. Any other machinery space shall be adequately ventilated, as appropriate for the purpose of that machinery space.

4.3.3 The ventilation of a closed engine room on board of tankers is to be arranged such that with an ambient temperature of 20°C the average temperature of the engine room will not exceed 40°C.

4.3.4 The supply of air for the main propulsion engine(s) may not been taken from spaces protected by a fixed fireextinguishing installation. This requirement is not applicable if two independent gastight separated machinery rooms are available or if next to the machinery room a steerable bow thruster installation is available in a separate engine room capable of propelling the ship in case of a main machinery room fire. Plans of the independent steerable bow thrust installation are to be submitted for consideration in such cases, *see Pt 5, Ch 17 Steerable Bow Thrusters*.

4.4 Fire protection

4.4.1 All surfaces of machinery where the surface temperature may exceed 220°C and where impingement of flammable liquids may occur, are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil, the insulation is to be encased in steel or equivalent.

4.5 Means of escape

4.5.1 In machinery spaces two means of escape are generally to be provided, *see Pt 3, Ch 6, 7.1 General*.

4.6 Communications

4.6.1 At least one means of communication is to be provided between the wheelhouse and the engine control station.

■ *Section 5*
Propulsion redundancy

5.1 Shaft system and steerable bow thruster

5.1.1 Ships having a length exceeding 110 m shall be fitted with:

- two independent shaft installations, each of the same power and a bow thrusters installation controlled from within the wheelhouse, or
- a single shaft installation together with an independent steerable bow thrust installation controllable from within the wheelhouse capable of propelling the ship by own means, also in the unloaded condition by failure of the main propulsion installation. Plans of the independent steerable bow thrust installations are to be submitted for consideration, *see Pt 5, Ch 17 Steerable Bow Thrusters*.

5.1.2 Passenger ships having a loaded waterline length exceeding 25 m shall be fitted with:

- A second independent propulsion system capable of propelling the ship in case of failure of the main propulsion system.
- The second independent system is to be installed in a separate machinery space, if both machinery spaces have a common boundary it is to be insulated to A60 Standard.

5.1.3 Combustion air for the main engines is not to be extracted from machinery spaces that are protected by permanently installed fire-fighting systems. This is not applicable when two independent completely separate machinery spaces are provided or if next to the main engine room a separate engine room has been provided with a bow thruster driven by its own source of power and capable of propelling the ship in the event of fire in the main machinery space.

■ *Section 6*
Trials

6.1 Inspection

6.1.1 Tests of components and trials of machinery, as detailed in the Chapters giving the requirements for individual systems, are to be carried out to the satisfaction of the Surveyors.

6.2 Trials

6.2.1 For all types of installation, the trials are to be of sufficient duration, and carried out under normal manoeuvring conditions, to prove the machinery under power. The trials are also to demonstrate that any vibration which may occur, within the operating speed range, is acceptable.

6.2.2 The trials are to include demonstrations of the following:

(a) The adequacy of the starting arrangements to provide the required number of starts of the main engines.

(b) The capability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal conditions, to bring the ship to rest from maximum ahead service speed.

6.2.3 Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern position. Where emergency manual pitch setting facilities are provided, their operation is to be demonstrated to the satisfaction of the Surveyor.

6.2.4 In geared installations, prior to full power trials, the gear teeth are to be suitably coated to demonstrate the contact markings, and on conclusion of the trials all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth. The marking is to indicate freedom from hard bearing, particularly towards the ends of the teeth, including both ends of each helix, where applicable. The contact is to be not less than that required by *Pt 5, Ch 3, 4.2 Accuracy of gear cutting and alignment* or *Pt 5, Ch 3, 5.2 Meshing tests*, as applicable.

6.2.5 The following information is to be available on board for the use of the Master and designated personnel:

- The results of trials to determine stopping times, ship headings and distance;
- For ships having multiple propellers, the results of trials to determine the ability to navigate and manoeuvre with one or more propellers inoperative.

6.2.6 Where the ship is provided with supplementary means for manoeuvring or stopping, such as a bow thruster, the effectiveness of such means are to be demonstrated.

6.2.7 All trials are to be to the Surveyor's satisfaction.

■ *Section 7*
Quality Assurance Scheme for Machinery

7.1 General

7.1.1 This certification scheme is applicable to both individual and series produced items manufactured under closely controlled conditions and will be restricted to works where the employment of quality control procedures is well established. LR will have to be satisfied that the practices employed will ensure that the quality of finished products is to standards which would be demanded when using traditional survey techniques.

7.1.2 The Committee will consider proposed designs for compliance with LR's Rules or other appropriate requirements and the extent to which the manufacturing processes and control procedure ensure conformity of the product to the design. A comprehensive survey will be made by the Surveyor of the actual operation of the quality control programme and of the adequacy and competence of the staff to implement it.

7.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

7.1.4 Approval by another organization will not be accepted as sufficient evidence that a manufacturer's arrangements comply with LR's requirements.

7.2 Requirements for approval

7.2.1 Details for approval to the requirements of this Quality Assurance Scheme for Machinery (QAM) are contained in *Pt 5, Ch 1, 6 Quality Assurance Scheme for Machinery* of the *Rules and Regulations for the Classification of Ships, July 2022*.

■ Scope

The requirements of this Chapter are applicable to reciprocating internal combustion engines operating on liquid, gas or dual fuel for main propulsion and essential auxiliary services (hereinafter referred to as engines). *Pt 5, Ch 2, 3 Design* is not applicable to auxiliary engines having powers of less than 110 kW.

The requirements for type testing of engines at the manufacturer's works are also included.

Arrangements for dual fuel engines and single-fuelled (gas) spark ignition or equivalent reciprocating engines will be specially considered.

Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it is to meet the requirements of *Pt 5, Ch 24 Emissions Abatement Plant for Combustion Machinery* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). Where secondary exhaust gas emissions abatement systems are fitted to engines, they are to meet the requirements of *Pt 5, Ch 24 Emissions Abatement Plant for Combustion Machinery* of the Rules for Ships.

■ *Section 1*
Plans and particulars

1.1 Plans

1.1.1 The following plans and particulars as applicable are to be submitted for consideration:

- Crankshaft assembly plan (for each crankthrow).
- Crankshaft details plan (for each crankthrow).
- Thrust shaft or intermediate shaft (if integral with engine).
- Output shaft coupling bolts.
- Main engine securing arrangements where non-metallic chocks are used.

- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, thrust bearing bedplate, crankcases, frames and entablatures. Details of materials welding consumables, fit-up conditions fabrication sequence and heat treatments are to be included.
- Schematic layouts of the following systems:

  Starting air.

  Fuel Oil.

  Lubricating oil.

  Cooling water.

  Control and safety.

  Hydraulic oil.
- Shielding of high pressure fuel pipes.
- Combustion pressure-displacement relationship.
- Crankshaft design data as outlined in *Pt 5, Ch 2, 3 Design*.
- High pressure parts for fuel oil injection system with specification of pressures, pipe dimensions and materials.
- For engine control, alarm monitoring and safety systems, the plans and information required by *Pt 6, Ch 1, 1.2 Documentation required for design review* of the Rules for Ships.
- For electronically controlled engines, the plans and information required by *Pt 5, Ch 2, 1.1 Plans 1.1.6*.

1.1.2 The following plans are to be submitted for information:

- Longitudinal and transverse cross-section.
- Cast bedplate, thrust bearing bedplate, crankcase and frames.
- Cylinder head assembly.
- Cylinder liner.
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Details of turbochargers, *see Pt 5, Ch 2, 11 Turbochargers*.
- Operation and service manuals.
- Vibration dampers/detuners and moment compensators.
- Thrust bearing assembly (if integral with engine and not integrated in the bedplate).
- Counterweights, where attached to crankthrow, including fastening.
- Main engine holding down arrangement (metal chocks).

1.1.3 Material specifications covering the listed components in *Pt 5, Ch 2, 1.1 Plans 1.1.1* and *Pt 5, Ch 2, 1.1 Plans 1.1.2* are to be forwarded together with details of any surface treatments, non-destructive testing and hydraulic tests.

1.1.4 For engine types built under license, it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor(s) attending the Licensee's works.

1.1.5 Where engines incorporate electronic control systems, the following additional information is to be submitted:

(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.
(b) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the functioning of sub-systems.
(c) A risk-based analysis of the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved in accordance with *Pt 5, Ch 2, 4.2 Risk-based analysis*.
(d) Details of hydraulic systems for actuation of sub-systems (fuel injection or exhaust), to include details of the design/ construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.
(e) Quality plan for sourcing, design, installation and testing of all components used in the fuel oil and hydraulic oil systems installed with the engine for engine operation.
(f) Fatigue analysis for all high pressure fuel oil and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.
(g) Evidence of type testing of the engine with the programmable electronic system, or a proposed test plan at the engine builders with the programmable electronic system functioning, to verify the functionality and behaviour under normal operation and fault conditions of the programmable electronic control system.
(h) Schedule of testing at Engine builders, pre-river trial commissioning and river trials. The test schedules are to identify all modes of engine operation and the river trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:
    (i) testing and trials to demonstrate that the engine is capable of operating as described in *Pt 5, Ch 2, 1.1 Plans 1.1.5*;
    (ii) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
    (iii) testing required to verify the conclusions of the risk-based analysis.

    The scope of these tests is to be agreed with LR.

1.1.6 In addition to the applicable plans and particulars required by *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.3* of the Rules for Ships the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details, *see Pt 5, Ch 2, 4.3 Control engineering systems 4.3.2*
(b) Software quality plans, including configuration management documents.
(c) Software safety evidence.
(d) Software assessment inspection report.

1.1.7 For Turbochargers, the following plans and particulars are to be submitted for information:

- Cross sectional plans of the assembled turbocharger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbocharger operating and test data.
- A selected turbocharger is to be type tested.

1.1.8 Where considered necessary, Lloyd's Register (hereinafter referred to as 'LR') may require additional documentation to be submitted.

Section 2
Materials

2.1 Crankshaft materials

2.1.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel castings – 400 to 550 N/mm^2.
(b) Carbon and carbon-manganese steel forgings (normalised and tempered) – 400 to 600 N/mm^2.
(c) Carbon and carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm^2.
(d) Alloy steel castings – not exceeding 700 N/mm^2.
(e) Alloy steel forgings – not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm^2.

2.1.2 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.2 Material test and inspections

2.2.1 Components for engines are to be tested as indicated in *Table 2.2.1 Test requirements for oil engine components* and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

Table 2.2.1 Test requirements for oil engine components

Component	Material tests	Non-destructive tests	
		Magnetic particle or Liquid penetrant	Ultrasonic
Crankshaft	all	all	all
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Connecting rods, including bearing caps	all	all	above 400 mm bore
Cylinder liner	above 300 mm bore	–	–
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	–	–
Plates for welded bedplates, frames and entablatures	all	–	–
Crankcases, welded or cast	all	–	–

Turbocharger, shaft and rotor	above 300 mm bore	–	–
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	–

Note 1. For closed-die forged crankshafts, the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.

Note 2. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.

Note 3. Bore dimensions refer to engine cylinder bores.

Note 4. All required material tests are to be witnessed by the Surveyor unless alternative arrangements have been specifically agreed by LR.

2.2.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 3* Design

3.1 Scope

3.1.1 The formulae given in this Section are applicable to solid crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

3.1.2 Alternative methods, including a fully documented stress analysis, will be specially considered.

3.1.3 Calculations are to be carried out for the maximum continuous power rating for all intended operating conditions.

3.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

3.2 Information to be submitted

3.2.1 In addition to detailed dimensioned plans, the following information is required to be submitted:

- Engine type – 4SCSA/2SCSA/in line/vee.
- Output power at maximum continuous rating (MCR), in kW.
- Output speed at maximum continuous power, in rpm.
- Maximum cylinder pressure, in bar g.
- Mean indicated pressure, in bar g.
- Cylinder air inlet pressure, in bar g.
- Digitised gas pressure/crank angle cycle for MCR.
- Maximum pressure/speed relationship.
- Compression ratio.
- Vee angle and firing interval (if applicable), in degrees.
- Firing order numbered from driving end, *see Figure 2.3.1 Designation of cylinders*.
- Cylinder diameter, in mm.
- Piston stroke, in mm.
- Mass of connecting rod (including bearings), in kg.
- Centre of gravity of connecting rod from large end centre, in mm.
- Radius of gyration of connecting rod, in mm.
- Length of connecting rod between bearing centres, in mm.
- Mass of single crankweb (indicate if webs either side of pin are of different mass values), in kg.

- Centre of gravity of crankweb mass from shaft axis, in mm.
- Mass of counterweights fitted (for complete crankshaft) indicate positions fitted, in kg.
- Centre of gravity of counterweights (for complete crankshaft) measured from shaft axis, in mm.
- Mass of piston (including piston rod and crosshead where applicable), in kg.
- All individual reciprocating masses acting on one crank, in kg.
- Material specification(s).
- Specified minimum UTS, in N/mm^2.
- Specified minimum yield strength, in N/mm^2.
- Method of manufacture.
- Details of fatigue enhancement process (if applicable).

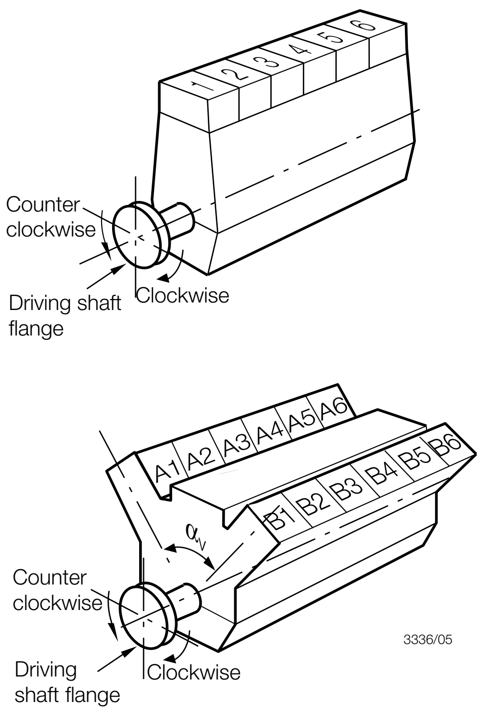


Figure 2.3.1 Designation of cylinders

3.3 Symbols

3.3.1 For the purposes of this Chapter, the following symbols apply (*see also Figure 2.3.2 Crank dimensions necessary for the calculation of stress concentration factors*):

h = radial thickness of web, in mm

k_e = bending stress factor

B = transverse breadth of web, in mm

D_p, D_j = outside diameter of pin or main journal, in mm

D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm

d_o = diameter of radial oil bore in crankpin, in mm

F = alternating force at the web centre line, in N

K_1 = fatigue enhancement factor due to manufacturing process

K_2 = fatigue enhancement factor due to surface treatment

M_b = alternating bending moment at web centre line, in N-mm (NOTE: alternating is taken to be $\frac{1}{2}$ range value)

M_{BON} = alternating bending moment calculated at the outlet of crankpin oilbore

M_p, M_j = undercut of fillet radius into web measured from web face, in mm

R_p, R_j = fillet radius at junction of web and pin or journal, in mm

S = stroke, in mm

T = axial thickness of web, in mm

T_a = alternating torsional moment at crankpin or crank journal, in N-mm (NOTE: alternating is taken to be $\frac{1}{2}$ range value)

U = pin overlap

= $\dfrac{D_p + D_j - S}{2}$ mm

α_B = bending stress concentration factor for crankpin

α_T = torsional stress concentration factor for crankpin

β_B = bending stress concentration factor for main journal

β_Q = direct shear stress concentration factor for main journal

β_T = torsional stress concentration factor for main journal

γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin

γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin

σ_{ax} = alternating axial stress, in N/mm^2

σ_b = alternating bending stress, in N/mm^2

σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2

σ_p, σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2

σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2

σ_Q = alternating direct stress, in N/mm^2

σ_u = specified minimum UTS of material, in N/mm^2

σ_y = specified minimum yield stress of material, in N/mm^2

τ_a = alternating torsional stress, in N/mm^2

τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2

τ_{tob} = maximum torsional stress in outlet of crankpin oil bore taking into account stress raisers, in N/mm^2.

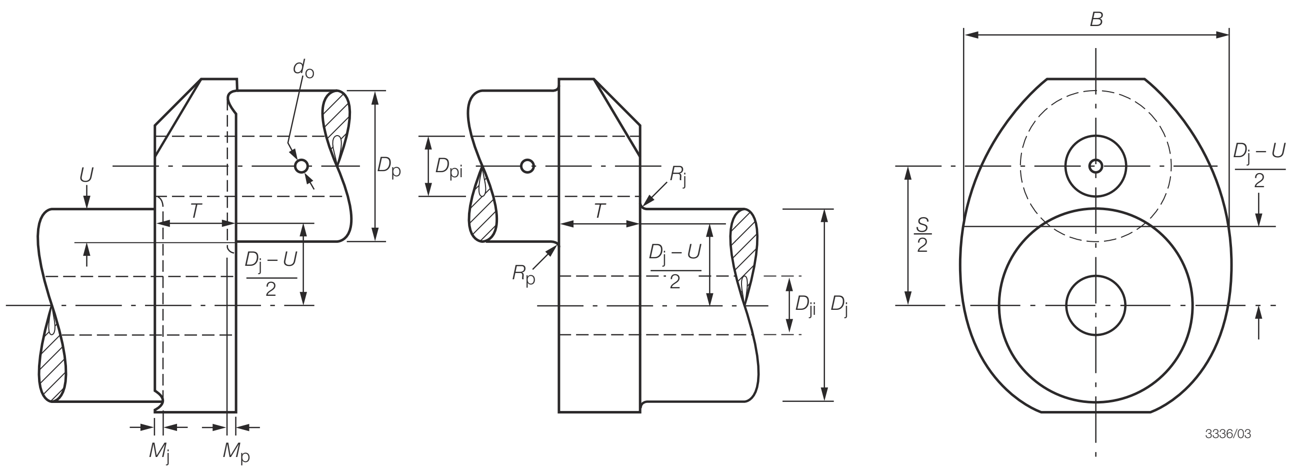


Figure 2.3.2 Crank dimensions necessary for the calculation of stress concentration factors

3.4 Stress concentration factors

3.4.1 **Geometric factors.** Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in *Table 2.3.1 Crankshaft variables*.

Table 2.3.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jB}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$ *See* Note 2		0,50

Note 1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.

Note 2. A lower limit of *u* can be extended down to large negative values provided that:

(i) If calculated *f*(rec) < 1 then the factor *f*(rec) is not to be considered (*f*(rec) = 1)

(ii) If *u* < –0,5 then *f*(ut) and *f*(ru) are to be evaluated replacing actual value of *u* by –0,5.

3.4.2 Crankpin stress concentration factors:

Bending

$$\alpha_B = 2{,}70\ f(ut).\ f(t).\ f(b).\ f(r).\ f(dp).\ f(dj).\ f(rec)$$

where

$f(ut) = 1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$

$f(t) = 2{,}18t^{0{,}717}$

$f(b) = 0{,}684 - 0{,}0077b + 0{,}147b^2$

$f(r) = 0{,}208r_p^{(-0{,}523)}$

$f(dp) = 1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$

$f(dj) = 1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$

$f(rec) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

valid only between $u = -0{,}5$ and $0{,}5$

Torsion

$$\alpha_T = 0{,}8\ f(ru).\ f(b).\ f(t)$$

where

$f(ru) = r_p^{-(0{,}22 + 0{,}1u)}$

$f(b) = 7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(t) = t^{(-0{,}145)}$

3.4.3 Crank journal stress concentration factors:

Bending

$$\beta_B = 2{,}71f_B(ut).\ f_B(t).\ f_B(b).\ f_B(r).\ f_B(dj).\ f_B(dp).\ f(rec)$$

where

$f_B(ut) = 1{,}2 - 0{,}5t + 0{,}32t^2 - u\,(0{,}80 - 1{,}15t + 0{,}55t^2) - u^2\,(2{,}16 - 2{,}33t + 1{,}26t^2)$

$f_B(t) = 2{,}24t^{0{,}755}$

$f_B(b) = 0{,}562 + 0{,}12b + 0{,}118b^2$

$f_B(r) = 0{,}191r_{jB}^{(-0{,}557)}$

$f_B(dj) = 1 - 0{,}644d_j + 1{,}23(d_j)^2$

$f_B(dp) = 1 - 0{,}19d_p + 0{,}0073(d_p)^2$

$f(rec) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

valid only between $u = -0{,}5$ and $0{,}5$

Direct shear

$$\beta_Q = 3{,}01f_Q(u).\ f_Q(t).\ f_Q(b).\ f_Q(r).\ f_Q(dp).\ f(rec)$$

where

$f_Q(u) = 1{,}08 + 0{,}88u - 1{,}52(u)^2$

where

$f_Q(t) = \dfrac{t}{(0,0637 + 0,937t)}$

$f_Q(b) = b - 0,5$

$f_Q(r) = 0,533 r_{JB}^{(-0,204)}$

$f_Q(dp) = 1 - 1,19 d_p + 1,74 (d_p)^2$

$f(rec) = 1 + (m_p + m_j)(1,8 + 3,2u)$

valid only between u = –0,5 and 0,5

Torsion

$\beta_T = 0,8 f(ru).\ f(b).\ f(t)$

where

$f(ru) = r_{jT}^{-(0,22 + 0,1u)}$

$f(b) = 7,9 - 10,65b + 5,35b^2 - 0,857b^3$

$f(t) = t^{(-0,145)}$

3.4.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

Bending

$$\gamma_B = 3 - 5,88 \cdot \frac{d_o}{D_p} + 34,6 \cdot \left(\frac{d_o}{D_p}\right)^2$$

Torsion

$$\gamma_T = 4 - 6 \cdot d_o \frac{d_o}{D_p} + 30 \cdot \left(\frac{d_o}{D_p}\right)^2$$

3.4.5 Where experimental measurements of the stress concentrations are available, these may be used. The full documented analysis of the experimental measurements are to be submitted for consideration.

3.5 Nominal stresses

3.5.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crankthrow simply supported at the mid length of the main journals.

3.5.2 Nominal bending stresses are referred to the web bending modulus.

3.5.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \text{ N/mm}^2$$

where

$Z_{web} = \dfrac{BT^2}{6} mm^2$

k_e = 0,8 for crosshead engines

= 1,0 for trunk piston engines.

3.5.4 Nominal alternating bending stress in the outlet of the crankpin oil bore:

$$\sigma_{BON} = \pm\frac{M_{BON}}{Z_{crankpin}}$$

where

M_{BON} is taken as the $\frac{1}{2}$ range value

$$M_{BON} = \pm\frac{1}{2}(M_{BOmax} - M_{BOmin})$$

and

M_{BO} = (M_{BTO} cosψ + M_{BRO} sinψ) *see Figure 2.3.3 Crankpin section through the oil bore*

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$$Z_{crankpin} = \frac{\pi}{32}\frac{\left(D^4 - d^4\right)}{D}$$

$Z_{crankpin}$ = related to the cross-section of axially bored crankpin.

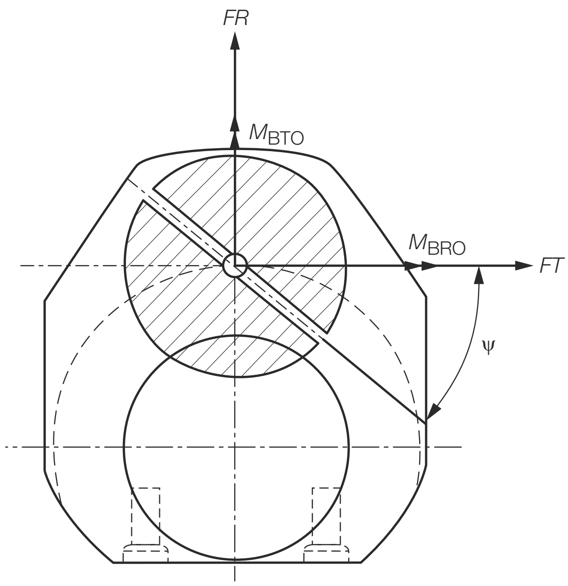


Figure 2.3.3 Crankpin section through the oil bore

3.5.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in *Pt 5, Ch 2, 3.5 Nominal stresses 3.5.3*.

3.5.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

3.5.7 Nominal alternating direct shear stress:

$$\sigma_Q = \pm\frac{F}{A_{web}}k_e \text{ N/mm}^2$$

where

A_{web} = BT mm^2.

3.5.8 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

3.5.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with *Pt 5, Ch 2, 2.2 Material test and inspections* are to be submitted.

3.5.10 Nominal alternating torsional stress:

$$\tau_a = \pm\frac{T_a}{Z_T} \text{ N/mm}^2$$

where

Z_T = torsional modulus of crankpin and main journal

$$= \frac{\pi}{16}\left[\frac{D^4 - d^4}{D}\right] \text{mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm.

τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring in one of the cylinders when no combustion occurs but only compression cycle). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

3.5.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in *Pt 5, Ch 2, 3.5 Nominal stresses 3.5.9*, occurring at the most torsionally loaded mass point of the crankshaft system.

3.5.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating torsional stress is not exceeded.

3.5.13 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk type engines, σ_{ax} = 0. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

3.6 Maximum stress levels

3.6.1 Crankpin fillet.

- Maximum alternating bending stress:

  $\sigma_p = \alpha_B (\sigma_b + \sigma_{ax})$ N/mm^2

where

α_B = bending stress concentration (*see Pt 5, Ch 2, 3.4 Stress concentration factors 3.4.2*)

- Maximum alternating torsional stress:

  $\tau_p = \alpha_T \tau_a$ N/mm^2

where

α_T = torsional stress concentration (*see Pt 5, Ch 2, 3.4 Stress concentration factors 3.4.2*)

τ_a = nominal alternating torsional stress in crankpin, in N/mm^2.

3.6.2 Outlet of crankpin oil bore:

- Maximum alternating bending stress:

$\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax})$ N/mm^2

where

γ_B = bending stress concentration factor, *see Pt 5, Ch 2, 3.4 Stress concentration factors 3.4.4*

- Maximum alternating torsional stress:

$T_{tob} = \gamma_T \tau_a$ N/mm^2

where

γ_T = torsional stress concentration factor, *see Pt 5, Ch 2, 3.4 Stress concentration factors 3.4.4*

τ_a = nominal alternating torsional stress in crankpin, in N/mm^2.

3.6.3 Crank journal fillet.

- Maximum alternating bending stress:

$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q$ N/mm^2

where

β_B = bending stress concentration (*see Pt 5, Ch 2, 3.4 Stress concentration factors 3.4.3*)

β_Q = direct stress concentration (*see Pt 5, Ch 2, 3.4 Stress concentration factors 3.4.3*)

- Maximum alternating torsional stress:

$\tau_j = \beta_T \tau_a$ N/mm^2

where

β_T = torsional stress concentration (*see Pt 5, Ch 2, 3.4 Stress concentration factors 3.4.3*)

τ_a = nominal alternating torsional stress in main journal, in N/mm^2.

3.7 Equivalent alternating stress

3.7.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal, σ_{ej}, is defined as:

$$\sigma_{ep}, \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \ \mathrm{N/mm^2}$$

where

σ = σ_p or σ_j N/mm^2

τ = τ_p or τ_j N/mm^2.

3.7.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3}\sigma_{bo}\left[1 + 2\sqrt{\frac{9}{4}\left(\frac{\sigma_{to}}{\sigma_{bo}}\right)^2}\right] \mathrm{N/mm^2}$$

3.8 Fatigue strength

3.8.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0,42\,\sigma_u + 39,3)\left(0,264 + 1,073 D_p^{-0,2} + \frac{(785 - \sigma_u)}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_p}}\right)$$

To calculate the fatigue strength in the oil bore area, replace R_p with $\frac{1}{2}$ do and σ_{fp} with σ_{fob}.

$$\sigma_{fj} = K_1 K_2 (0,42\,\sigma_u + 39,3)\left(0,264 + 1,073 D_j^{-0,2} + \frac{(785 - \sigma_u)}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_j}}\right)$$

where

σ_u = UTS of crankpin or crank journal as appropriate

K_1 = fatigue endurance factor appropriate to the manufacturing process

= 1,05 for continuous grain-flow (CGF) or die-forged

= 1,0 for freeform forged (without CGF)

= 0,93 for cast steel manufactured using a LR approved cold rolling process

K_2 = fatigue enhancement factor for surface treatment.

= These treatments are to be applied to the fillet radii.

A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened

= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied, then details of the manufacturing process are to be submitted.

3.9 Acceptability criteria

3.9.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e} \text{ for crankpin, journal and the outlet of crankpin oil bore}$$

where

σ_f = σ_{fp} or σ_{fj} or σ_{fob}

σ_e = σ_{ep} or σ_{ej} or σ_{eob}.

3.10 Oil hole

3.10.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

3.10.2 Fatigue strength calculations or alternatively fatigue test results may be required to demonstrate acceptability.

3.10.3 When journal diameter is equal to or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

3.11 Shrink fit of semi-built crankshafts

3.11.1 For requirements, *see* the Rules for Ships, *Pt 5, Ch 2, 3.13 Shrink fit of semi-built crankshafts*.

3.12 Alternative method for calculation of stress concentration factors

3.12.1 LR will give consideration to crankshaft design using an alternative method given in the LR *Guidance Notes for the Calculation of Stress Concentration Factors, Fatigue Enhancement Methods and Evaluation of Fatigue Tests for Crankshafts*.

■ *Section 4* Electronically controlled engines

4.1 General

4.1.1 The requirements of this Section are applicable to engines for propulsion and auxiliary purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

4.1.2 These engines may be of the slow, medium or high-speed type. They generally have no direct camshaft - driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the fuel, air and exhaust systems.

4.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

4.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of technical justification produced by the Engine builder.

4.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary engines.

4.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

4.2 Risk-based analysis

4.2.1 An analysis is to be carried out in accordance with relevant standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and ship and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in *Pt 5, Ch 2, 4.2 Risk-based analysis 4.2.2* to *Pt 5, Ch 2, 4.2 Risk-based analysis 4.2.4* relevant to the engine application.

4.2.2 For ships with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:

(a) Will not result in the loss of the ability to provide the services essential for the operation of the engine, *see Pt 6, Ch 1, 2.5 Control systems, general requirements 2.5.7* and *Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.2* of the Rules for Ships;

(b) Will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems 2.14.4* and *Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems 2.14.5* of the Rules for Ships: and

(c) Will not leave either the engine, or any equipment or machinery associated with the engine, or the ship in an unsafe condition, *see Pt 6, Ch 1, 2.3 Alarm systems, general requirements 2.3.14*, *Pt 6, Ch 1, 2.4 Safety systems, general requirements 2.4.5*, *Pt 6, Ch 1, 2.4 Safety systems, general requirements 2.4.4*, *Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements 2.10.3*, *Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements 2.10.4* and *Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems 2.14.5* of the Rules for Ships.

4.2.3 A risk-based analysis is to be carried out for:

(a) main engines on ships with multiple main engines or other means of providing propulsion power; and/or

(b) auxiliary engines intended to drive electric generators forming the ship's main source of electrical power or otherwise providing power for essential services.

The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall ship installation with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the ship. Arrangements satisfying the criteria of *Pt 5, Ch 2, 4.2 Risk-based analysis 4.2.2* will also be acceptable.

4.2.4 The risk-based analysis report is to:

(a) Identify the standards used for analysis and system design.
(b) Identify the engine, its purpose and the associated objectives of the analysis.
(c) Identify any assumptions made in the analysis.
(d) Identify the equipment, system or sub-system, mode of operation and the equipment.
(e) Identify potential failure modes and their causes.
(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode.
(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.).
(h) Identify trials and testing necessary to prove conclusions.

4.2.5 At sub-system level it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

4.3 Control engineering systems

4.3.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with *Pt 6, Ch 1 Control Engineering Systems* of the Rules for Ships as applicable.

4.3.2 The engine control, alarm monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shut-downs, etc.) of this Chapter and *Pt 6, Ch 1 Control Engineering Systems* of the Rules for Ships for an engine for main or auxiliary purposes. Details of the engine configuration are to be submitted for consideration identifying:

(a) Local and remote means to carry out system configuration.
(b) Engine builder procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g. Engine builder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion, auxiliary engine application.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with *Pt 6, Ch 1, 1.5 Alterations and additions* and *Pt 6, Ch 1, 7.1 General 7.1.3* of the Rules for Ships.

4.4 Software

4.4.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.2* and *Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.7* of the Rules for Ships.

4.4.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the Engine builder. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements,* or other relevant standards or codes acceptable to LR, will generally be acceptable.

4.4.3 To demonstrate compliance with *Pt 5, Ch 2, 4.4 Software 4.4.1* and *Pt 5, Ch 2, 4.4 Software 4.4.2*:

(a) software quality plans and safety evidence are to be submitted for consideration, *see Pt 5, Ch 2, 4.2 Risk-based analysis 4.2.2.(b)* and *Pt 5, Ch 2, 4.2 Risk-based analysis 4.2.2.(c)*; and
(b) an assessment inspection of the Engine builder's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

Section 5
Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves required by *Pt 5, Ch 2, 7 Crankcase safety fitting*, and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double-welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders, the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

5.3.2 Welding is to be carried out in accordance with the requirements of *Ch 13 Requirements for Welded Construction* of the Rules for Materials, using welding procedures and welders that have been qualified in accordance with *Ch 12 Welding Qualifications* of the Rules for Materials.

5.3.3 Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned.

5.3.4 The welding is to be carried out in positions free from draughts and is to be downhand (flat) wherever practicable. Welding consumables are to be suitable for the materials being joined. Preheating is to be adopted when heavy plates or sections are welded. The finished welds are to have an even surface and are to be free from undercutting.

5.3.5 Welds attaching bearing housings to the transverse girders are to have a smooth contour and, if necessary, are to be made smooth by grinding.

5.4 Post-weld heat treatment

5.4.1 Bedplates are to be given a stress relieving heat treatment except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need be stress relieved.

5.4.2 Stress relieving is to be carried out by heating the welded structure uniformly and slowly to a temperature between 580°C and 620°C, holding that temperature for not less than one hour per 25 mm of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

5.4.3 Omission of post-weld heat treatment of bedplates and their sub-assemblies will be considered on application by the Enginebuilder with supporting evidence in accordance with *Ch 13, 2.10 Post-weld heat treatment 2.10.6* of the Rules for Materials.

5.5 Inspection

5.5.1 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding.

5.5.2 Inspection of welds is to be in accordance with the requirements of *Ch 13, 1.11 Non-destructive examination of welds* of the Rules for Materials.

5.5.3 Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyor. Other joints are to be similarly tested if required by the Surveyor.

■ *Section 6* Safety arrangements on engines

6.1 Cylinder relief valves

6.1.1 Cylinder relief valves are to be fitted to engines having cylinders over 230 mm bore. The valves are to be loaded to not more than 40 per cent above the designed maximum pressure and are to discharge safely so that no damage occurs.

6.1.2 In the case of auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

6.1.3 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

6.2 Main engine governors

6.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

6.2.2 Oil engines coupled to electrical generators which are the source of power for main electric propulsion motors are to comply with the requirements for auxiliary engines in respect of governors and overspeed protection devices.

6.3 Auxiliary engine governors

6.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or, when after having run on no-load for at least 15 minutes, load is suddenly applied as follows:

(a) For engines with BMEP less than 8 bar, full load, or

(b) For engines with BMEP greater than 8 bar, $\frac{800}{\text{BMEP}}$ per cent, but not less than one-third, of full load, the full load being attained in not more than two additional equal stages as rapidly as possible.

6.3.2 Emergency engines are to comply with *Pt 5, Ch 2, 6.3 Auxiliary engine governors 6.3.1* except that the initial load required by *Pt 5, Ch 2, 6.3 Auxiliary engine governors 6.3.1.(b)* is to be not less than the total connected emergency statutory load.

6.3.3 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with *Pt 5, Ch 2, 6.3 Auxiliary engine governors 6.3.1* are to return to and remain within one per cent of the final steady state speed. This should normally be accomplished within five but in no case more than eight seconds. For quality of power supplies, *see Pt 6, Ch 2, 1.4 Application 1.4.3*.

6.4 Overspeed protective devices

6.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

6.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by *Pt 5, Ch 2, 6.2 Main engine governors* or *Pt 5, Ch 2, 6.3 Auxiliary engine governors* and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

■ *Section 7* Crankcase safety fitting

7.1 NOTE For the purpose of this Section, starting air compressors are to be treated as auxiliary engines

7.2 Relief valves

7.2.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

7.2.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

7.2.3 The discharge from the valves is to be shielded by flame guard or flame trap to minimize the possibility of danger and damage arising from the emission of flame.

7.3 Number of relief valves

7.3.1 In engines having cylinders not exceeding 200 mm bore and having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

7.3.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crankthrows an additional valve is to be fitted near the centre of the engine.

7.3.3 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crankthrow with a minimum of two valves. For engines having 3, 5, 7, 9, etc. crankthrows, the number of relief valves is not to be less than 2, 3, 4, 5, etc. respectively.

7.3.4 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crankthrow.

7.3.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

7.4 Size of relief valves

7.4.1 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

7.4.2 The free area of each relief valve is to be not less than 45 cm^2.

7.4.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

7.4.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

7.5 Vent pipes

7.5.1 Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vents or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

7.5.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

7.5.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

7.6 Warning notice

7.6.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

■ *Section 8* **Piping**

8.1 Fuel oil, hydraulic and high pressure oil systems

8.1.1 Fuel oil and hydraulic oil piping systems arrangements are to comply with Chapters*Pt 5, Ch 10 Piping Design Requirements* and *Pt 5, Ch 12 Machinery Piping Systems* as applicable.

8.1.2 Fuel oil pipe systems in general, tanks and their fittings are to comply with the requirements of *Pt 5, Ch 12 Machinery Piping Systems* and *Pt 3 Ship Structures (General)*.

8.1.3 Each fuel oil pump and hydraulic oil pump essential for engine operation is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating.

8.1.4 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

8.1.5 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system capable of containing hydraulic oil leakage from a high pressure pipe failure.

8.1.6 Where flammable oils are used in high-pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a highpressure line failure.

8.1.7 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

8.1.8 Engine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. In particular, this applies to the fuel injection pump supply and spill line piping which may be subject to high-pressure pulses from the pump. Connections on such piping systems should be chosen to minimise the risk of pressurised fuel oil leaks.

8.1.9 The protection is to prevent fuel oil or fuel oil mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any fuel oil leakage to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place.

8.1.10 All valves, cocks and screwed connections are to be of a type tested type applicable to the maximum service conditions anticipated in normal service.

8.1.11 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the fuel oil and hydraulic oil installation are to be capable of being controlled from readily accessible positions above the working platform.

8.1.12 High pressure fuel oil and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

8.1.13 High pressure fuel oil and high pressure hydraulic piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

8.1.14 Equipment fitted for monitoring pressures and temperatures in the high pressure fuel oil and high pressure hydraulic oil systems is to comply with a Recognised Standard suitable to the anticipated vibration and temperature conditions.

8.1.15 A fatigue analysis is to be carried out in accordance with a standard applicable to the system under consideration and all anticipated pressure, pulsation and vibration loads are to be addressed. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing of the system. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

8.1.16 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

8.2 Exhaust systems

8.2.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220ºC, they are to be water cooled or efficiently lagged to minimize the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

8.2.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

8.2.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economizer, an isolating device is to be provided in each exhaust pipe.

8.2.4 Exhaust gases are to be led overboard and should be blown out in a direction away from the ship.

8.3 Starting air pipe systems and safety fittings

8.3.1 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

8.3.2 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

8.3.3 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

8.3.4 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

8.3.5 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

8.3.6 In direct reversing engines, bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines, at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

8.3.7 Alternative safety arrangements may be submitted for consideration.

8.4 *Cross-reference*

8.4.1 The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of *Pt 5, Ch 12 Machinery Piping Systems*.

■ *Section 9*
Starting arrangements, air compressors and batteries

9.1 Air compressors

9.1.1 Where compressed air is used for starting and manoeuvring purposes, the following arrangements are to be provided as applicable:

(a) **Main engine driven compressor provided**. An additional independently power driven compressor is to be fitted. If this compressor is driven by an auxiliary engine, the engine is to be of a hand or electric started type. Alternatively, other devices of an approved type may be accepted in lieu of the independently driven compressor.

(b) **Main engine driven compressor not provided**. Two independently power driven compressor are to be fitted. If the compressors are driven by auxiliary engines, at least one of the engines is to be of a hand or electric started type.

9.1.2 The air compressors fitted should have a total capacity capable of charging the air receivers within one hour from atmospheric pressure to the pressure sufficient for the number of starts required by *Pt 5, Ch 2, 9.2 Air receiver capacity*. The capacity of the air compressors is to be approximately equally divided between them.

9.1.3 Power driven compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature.

9.1.4 Each power driven compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

9.1.5 Air compressors are to be in accordance with *Pt 5, Ch 2, 13 Air compressors* of the Rules for Ships, which includes requirements for the design, materials, safety precautions and for the manufacture and testing of air compressors.

9.2 Air receiver capacity

9.2.1 Where the main engine is arranged for air starting, the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see Pt 5, Ch 9 Pressure Vessels other than Boilers*.

9.2.2 For multi-screw installations with one engine per shaft line, the following requirements apply:

(a) For reversing engines, 12 consecutive starts per engine required.

(b) For non reversing engines driven by a CPP installation, six consecutive starts per engine required.

(c) For non reversing engines with reverse reduction gears for fixed or CPP shafting installations, six consecutive starts per engine are required.

9.3 Electric starting

9.3.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by *Pt 5, Ch 2, 9.2 Air receiver capacity 9.2.1* and *Pt 5, Ch 2, 9.2 Air receiver capacity 9.2.2*. In other respects batteries are to comply with the requirements of *Pt 6, Ch 2 Electrical Installations*.

9.3.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

9.3.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

9.3.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own monitoring arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines, as defined in *Pt 5, Ch 2, 9.3 Electric starting 9.3.1* and *Pt 5, Ch 2, 9.3 Electric starting 9.3.3*.

9.3.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery charge level.

■ *Section 10* Component tests and engine type testing

10.1 Hydraulic tests

10.1.1 In general, items are to be tested by hydraulic pressure as indicated in *Table 2.10.1 Test pressures for oil engine components*. Where design features are such that modifications to the test requirements shown in *Table 2.10.1 Test pressures for oil engine components* are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

Table 2.10.1 Test pressures for oil engine components

Item		Test Pressure
Fuel injection system	Pump body, pressure side Valve Pipe	The lesser of 1,5p or p + 295 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)		7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbocharger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)		The greater of 4,0 bar or 1,5p
Air compressor, including cylinders, covers, intercoolers and aftercoolers		Air side: 1,5p Water side: The greater of 4,0 bar or 1,5p

Scavenge pump cylinder	4,0 bar
Note 1. *p* is the maximum working pressure in the item concerned. Note 2. Fuel pumps of the jerk or timed pump system are not included. Note 3. Turbocharger air coolers need only be tested on the water side. Note 4. For forged steel cylinder covers alternative testing methods will be specially considered.	

10.2 Engine type testing

10.2.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation.

10.2.2 Guidelines for type testing of engines will be supplied on application.

10.2.3 An engine type is defined in terms of:

- basic engine data: e.g. bore, stroke;
- working cycle: 2 stroke, 4 stroke;
- cylinder arrangement: in-line, vee;
- cylinder rating;
- fuel supply: e.g. direct, or indirect injection, dual fuel;
- gas exchange: natural aspiration, pressure charging arrangement.

10.2.4 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

10.2.5 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

■ *Section 11* Turbochargers

11.1 Type test

11.1.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbocharger is to be completely dismantled for examination of all parts.

11.1.2 Alternative arrangements will be specially considered.

11.2 Dynamic balancing

11.2.1 All rotors are to be dynamically balanced on final assembly to the Surveyor’s satisfaction.

11.3 Overspeed test

11.3.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

11.4 Mechanical running test

11.4.1 Turbochargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

11.4.2 Upon application, with details of an historical audit covering previous testing of turbochargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test outlined in *Pt 5, Ch 2, 11.4 Mechanical running test 11.4.1* to a representative sample of turbochargers.

Scope

The requirements of this Chapter, except where otherwise stated, are applicable to engine gearing for main propulsion purposes and for engine gearing for driving auxiliary machinery which is essential for the safety of the ship or for safety of persons on board where the transmitted powers exceed 220 kW for propulsion drives, and 110 kW for auxiliary drives. Alternatively, calculations using the methods defined in ISO 6336 – *Calculation of load capacity of spur and helical gears* will be considered. In any mesh, the terms ‘pinion’ and ‘wheel’ refer to the smaller and larger gear respectively. Bevel gears will be specially considered on the basis of a conversion to equivalent helical gears. For torsional vibration requirements, *see Pt 5, Ch 6, 2.3 Scope of calculations*.

Section 1
Plans and particulars

1.1 Gearing plans

1.1.1 Particulars of the gearing are to be submitted with the plans for all propulsion gears and for auxiliary gears where the transmitted power exceeds 110 kW, as follows:

(a) Plans and information demonstrating conformance with the applicable Rules and Standards as stated in scope.
(b) Shaft power and revolution for each pinion.
(c) Number of teeth in each gear.
(d) Reference diameters.
(e) Helix angles at reference diameters.
(f) Normal pitches of teeth at reference diameters.
(g) Tip diameters.
(h) Root diameters.
(i) Face widths and gaps, where applicable.
(j) Pressure angles of teeth (normal or transverse) at reference diameters.
(k) Accuracy grade Q in accordance with ISO 1328 or an equivalent standard.
(l) Surface texture of tooth flanks and roots.
(m) Minimum backlash.
(n) Centre distance.
(o) Basic rack tooth form.
(p) Protuberance and final machining allowance.
(q) Details of post hobbing processes, if any.
(r) Details of tooth flank corrections, if adopted.

(s) Case depth for surface-hardened teeth.
(t) Shrinkage allowance for shrunk-on rims and hubs.
(u) Type of coupling proposed for engine applications.

1.2 Material specifications

1.2.1 Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels and quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval with the plans of gearing.

1.2.2 Where the teeth of a pinion or gear wheel are to be surface hardened, i.e. carburized, nitrided, tufftrided or induction-hardened, the proposed specification and details of the procedure are to be submitted for approval.

■ *Section 2* Materials

2.1 Material properties

2.1.1 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

2.1.2 Subject to *Pt 5, Ch 3, 2.1 Material properties 2.1.1*, the specified minimum tensile strength is to be selected within the following limits:

Pinion and pinion sleeves	550 to 1050 N/mm^2
Gear wheels and rims	400 to 850 N/mm^2

A tensile strength range is also to be specified and is not to exceed 120 N/mm^2 when the specified minimum tensile strength is 600 N/mm^2 or less. For higher strength steels, the range is not to exceed 150 N/mm^2.

2.1.3 Unless otherwise agreed, the full specified minimum tensile strength of the core is to be 800 N/mm^2 for induction-hardened or nitrided gearing and 750 N/mm^2 for carburized gearing.

2.1.4 For nitrided gearing, the full depth of the hardened zone is to be not less than 0,5 mm and the hardness is to be not less than 500 Hv for a depth of 0,25 mm.

2.2 Non-destructive tests

2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

■ *Section 3* Design

3.1 Symbols

3.1.1 For the purposes of this Chapter, the following symbols apply:

a = centre distance, in mm

b = facewidth, in mm

d = reference diameter, in mm

d_a = tip diameter, in mm

d_{an} = virtual tip diameter, in mm

d_b = base diameter, in mm

d_{bn} = virtual base diameter, in mm

d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm

d_f = root diameter, in mm

d_{fn} = virtual root diameter, in mm

d_n = virtual reference diameter, in mm

d_s = shrink diameter, in mm

d_w = pitch circle diameter, in mm

f_{ma} = tooth flank misalignment due to manufacturing errors, in μm

f_{pb} = maximum base pitch deviation of wheel, in μm

f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in μm

f_{Sho} = intermediary factor for the determination of f_{Sh}

g_α = length of line of action for external gears, in mm:

$$= 0.5\sqrt{\left(d^2{}_{a1} - d^2{}_{b1}\right)} + 0,5\sqrt{\left(\mathrm{d}^2{}_{a2} - \mathrm{d}^2{}_{b2}\right)} + \mathrm{a}\sin\alpha_{\mathrm{tw}}$$

= for internal gears:

$$= 0.5\sqrt{\left(d^2{}_{a1} - d^2{}_{b1}\right)} + 0,5\sqrt{\left(\mathrm{d}^2{}_{a2} - \mathrm{d}^2{}_{b2}\right)} + \mathrm{a}\sin\alpha_{\mathrm{tw}}$$

h = total depth of tooth, in mm

h_{ao} = basic rack addendum of tool, in mm

h_F = bending moment arm for root stress, in mm

h_W = sum of actual tooth addenda of pinion and wheel, in mm

m_n = normal module, in mm

n = rev/min of pinion

q = machining allowances, in mm

q_s = notch parameter

q' = intermediary factor for the determination of C_γ

u = gear ratio $= \dfrac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$

v = linear speed at pitch circle, in m/s

x = addendum modification coefficient

y_{α} = running in allowance, in μm

y_{β} = running in allowance, in μm

z = number of teeth

z_{n} = virtual number of teeth

$$= \frac{z}{\cos^2 \beta_{b} \cos \beta}$$

C_{γ} = tooth mesh stiffness (mean total mesh stiffness per unit facewidth), in N/mm μm

F_{t} = nominal tangential tooth load, in N

$$= \frac{P}{nd} 19,098 \times 10^6$$

F_{β} = total tooth alignment deviation (maximum value specified), in μm

$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm

$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm

HV = Vickers hardness number

K_{A} = application factor

$K_{F\alpha}$ = transverse load distribution factor

$K_{F\beta}$ = longitudinal load distribution factor

$K_{H\alpha}$ = transverse load distribution factor

$K_{H\beta}$ = longitudinal load distribution factor

K_{v} = dynamic factor

$K_{v\alpha}$ = dynamic factor for spur gears

$K_{v\beta}$ = dynamic factor for helical gears

K_{γ} = load sharing factor

P = transmitted power, in kW

P_{r} = radial pressure at shrinkage surface, in N/mm^2

P_{ro} = protuberance of tool, in mm

Q = accuracy grade derived from ISO 1328 Cylindrical gears – ISO system of accuracy

R_{a} = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in μm

S_{pr} = residual undercut left by protuberance in mm

$S_{F\,min}$ = minimum factor of safety for bending stress

S_{Fn} = tooth root chord in the critical section, in mm

$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress

Y_D = design factor

Y_F = tooth form factor

$Y_{R\,rel\,T}$ = relative surface finish factor

Y_S = stress concentration factor

Y_{ST} = stress correction factor

Y_x = size factor

Y_β = helix angle factor

$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor

Z_E = material elasticity factor

Z_H = zone factor

Z_R = surface finish factor

Z_V = velocity factor

Z_X = size factor

Z_β = helix angle factor

Z_ϵ = contact ratio factor

α_{en} = pressure angle at the highest point of single tooth contact, in degrees

α_n = normal pressure angle at reference diameter, in degrees

α_t = transverse pressure angle at reference diameter, in degrees

α_{tw} = transverse pressure angle at pitch circle diameter, in degrees

$\alpha_{F\,en}$ = angle for application of load at the highest point of single tooth contact, in degrees

β = helix angle at reference diameter, in degrees

β_b = helix angle at base diameter, in degrees

γ = intermediary factor for the determination of f_{Sh}

ε_α = transverse contact ratio

$$= \frac{g_\alpha \cos\beta}{\pi\, m_n \cos\alpha_t}$$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio

ε_{β} = overlap ratio

$= \dfrac{b \sin \beta}{\pi m_n}$

ε_{γ} = total contact ratio

ρ_{ao} = tip radius of tool, in mm

ρ_{C} = relative radius of curvature at pitch point, in mm

$= \dfrac{a \sin \alpha_{tw} u}{\cos \beta_b \left(1 + u^2\right)}$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm

σ_y = yield or 0,2 per cent proof stress, in N/mm^2

σ_B = ultimate tensile strength, in N/mm^2

σ_F = bending stress at tooth root, N/mm^2

$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2

σ_{FP} = allowable bending stress at the tooth root, in N/mm^2

σ_H = Hertzian contact stress at the pitch circle, in N/mm^2

$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2

σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript:

1 = pinion

2 = wheel

0 = tool.

3.2 Tooth form

3.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0,25 m_n.

3.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

3.3 Tooth loading factors

3.3.1 For values of application factor, K_A, *see Table 3.3.1 Values of* K_A.

Table 3.3.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10

High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary gears:	
Electric and engine drives with hydraulic coupling or equivalent on input	1,0
Engine drives with high elastic coupling on input	1,20
Engine drives with other couplings	1,40

3.3.2 Load sharing factor, K_{γ}. The value for K_{γ} is to be taken as 1,15 for multi-engine drives or split torque arrangements. Otherwise K_{γ} is to be taken as 1. Alternatively, where measured data exists, a derived value will be considered.

3.3.3 Dynamic factor, K_{v}:

For helical gears with $\epsilon_{\beta} \geq 1$:

$K_{v} = 1 + Q^{2} v z_{1} 10^{-5} = K_{v\beta}$

For helical gears with $\epsilon_{\beta} < 1$:

$K_{v} = K_{v\alpha} - \epsilon_{\beta} (K_{v\alpha} - K_{v\beta})$

For spur gears:

$K_{v} = 1 + 1{,}8 Q^{2} v z_{1} 10^{-5} = K_{v\alpha}$

where $\frac{v z_1}{100} > 14$ for helical gears, and

where $\frac{v z_1}{100} > 10$ for spur gears, the value of K_{v} will be

specially considered.

3.3.4 Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:

$$K_{H\beta} = 1 + \frac{b F_{\beta y} C_{\gamma}}{2 F_t K_A K_{\gamma} K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$F_{\beta y} = F_{\beta x} - y_{\beta}$ and

$F_{\beta x} = 1{,}33 f_{Sh} + f_{ma}$

$f_{ma} = \frac{2}{3} F_{\beta}$ at the design stage, or

$f_{ma} = \frac{1}{3} F_{\beta}$ where helix correction has been applied

$$f_{Sh} = f_{Sho} \frac{F_t K_A K_{\gamma} K_v}{b}$$

where

$f_{Sho} = 23\gamma 10^{-3}$ µm mm/N for gears without helix correction and without end relief, or

$= 16\gamma 10^{-3}$ µm mm/N for gears without helix correction but with end relief

$\gamma = \left(\frac{b}{d_1}\right)^2$ for single helical and spur gears

$= 3\left(\frac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:

f_{Sho} = 10 x 10^{-3} µm mm/N for helical gears, or

= 5 x 10^{-3} µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

$y_\beta = \frac{320}{\sigma_{\mathrm{H\,lim}}} F_{\beta x}$ when

$y_\beta = \leq \frac{12800}{\sigma_{\mathrm{H\,lim}}}$

For surface hardened steels, when

$y_\beta = 0{,}15 F_{\beta x}$

$y_\beta = \leq 6$ µm

$K_{F\beta} = K_{H\beta}{}^{n}$

where

$$n = \frac{\left(\frac{b}{h}\right)^2}{1 + \frac{b}{h} + \left(\frac{b}{h}\right)^2}$$

Note 1. $\frac{b}{h}$ is to be taken as the smaller of $\frac{b_1}{h_1}$ or $\frac{b_2}{h_2}$

Note 2. For double helical gears is to be substituted for *b* in the equation for *n*.

3.3.5 Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$

$K_{H\alpha} = K_{F\alpha} \geq 1{,}00$

where

$\epsilon_\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon_\gamma}{2}\left\{0,9 + \frac{0,4C_\gamma\left(f_{\mathrm{pb}} - y_\alpha\right)^b}{F_t K_A K_\gamma K_v K_{H\beta}}\right\}$$

where

$\epsilon_\gamma > 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2\left(\varepsilon_\gamma - 1\right)}{\varepsilon_\gamma}}\left\{\frac{C_\gamma\left(f_{\mathrm{pb}} - y_\alpha\right)b}{F_t K_A K_\gamma K_v K_{H\beta}}\right\}$$, but

$K_{H\alpha}$ = $\leq \dfrac{\varepsilon_{\gamma}}{\varepsilon_{\alpha} Z_{\varepsilon}^{2}}$ and

$K_{F\alpha}$ = $\leq \dfrac{\varepsilon_{\gamma}}{0,25\,\varepsilon_{\gamma} + 0,75}$ and

When tip relief is applied, f_{pb} is to be half of the maximum specified value:

y_{α} = $\dfrac{160}{\sigma_{H\,lim}} f_{pb}$ for through-hardened steels, when

y_{α} = $\dfrac{6400}{\sigma_{H\,lim}}$ µm and

y_{α} = $0,075 f_{pb}$ for surface hardened steels, when

y_{α} = ≤ 3 µm

When pinion and wheel are manufactured from different materials:

y_{α} = $\dfrac{y_{\alpha 1} + y_{\alpha 2}}{2}$

3.3.6 Tooth mesh stiffness, C_{γ} :

C_{γ} = $\dfrac{0,8}{q'} \cos\beta\,(0,75\epsilon_{\alpha} + 0,25)$ N/mm µm

where

q' = $0,04723 + \dfrac{0,1551}{Z_{n1}} + \dfrac{0,25791}{Z_{n2}} - 0,00635 x_{1} - \dfrac{0,11654 X_{1}}{Z_{n1}} - 0,00193 x_{2} - \dfrac{0,24188 X_{2}}{Z_{n1}} + 0,00529 x_{1}^{2} + 0,00182 x_{2}^{2}$

For internal gears $z_{n2} = \infty$

Other calculation methods for C_{γ} will be specially considered.

3.4 Tooth loading for surface stress

3.4.1 The Hertzian contact stress, σ_{H}, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}.

σ_{H} = $Z_{H} Z_{E} Z_{\epsilon} Z_{\beta} \sqrt{\dfrac{F_{t}(u+1)}{d_{1} b u} K_{A} K_{\gamma} K_{v} K_{H\beta} K_{H\alpha}}$ and

σ_{HP} = $\dfrac{\sigma_{H\,lim} Z_{R} Z_{V} Z_{X}}{S_{H\,min}}$ for the pinion/wheel combination.

where

Z_{H} = $\sqrt{\dfrac{2\cos\beta_{b}\cos\alpha_{tw}}{\cos^{2}\alpha_{t}\sin\alpha_{tw}}}$

Z_{E} = 189,8 for steel

Z_{ϵ} = $\sqrt{\dfrac{4-\varepsilon_{\alpha}}{3}\left(1-\varepsilon_{\beta}\right) + \dfrac{\varepsilon_{\beta}}{\varepsilon_{\alpha}}}$ for $\epsilon_{\beta} < 1$ and

$$Z_{\epsilon} = \sqrt{\frac{1}{\varepsilon_{\alpha}}} \text{ for } \epsilon_{\beta} \geq 1$$

$$Z_{\beta} = \sqrt{\cos \boldsymbol{\beta}}$$

$$Z_{R} = \left(\frac{1}{R_{a}}\right)^{0,11} \text{ but } Z_{R} \leq 1,14$$

where

R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ, then the larger value of R_a is to be taken.

$$Z_{v} = 0,88 + 0,23\left(0,8 + \frac{32}{v}\right)^{-0,5}$$

For values of Z_x, *see Table 3.3.2 Values of Z_x*

For values of $\sigma_{H\,lim}$, *see Table 3.3.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$*

For values of $S_{H\,min}$, *see Table 3.3.4 Factors of safety*.

Table 3.3.2 Values of Z_x

Pinion heat treatment		Z_x
Carburized and induction-hardened	$m_n \leq 10$	1,0
	$10 < m_n < 30$	$1,05 - 0,005m_n$
	$30 \leq m_n$	0,9
Nitrided	$m_n < 7,5$	1,0
	$7,5 < m_n < 30$	$1,08 - 0,011m_n$
	$30 \leq m_n$	0,75
	All modules	1,0

Table 3.3.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$

Heat Treatment		
Pinion	Wheel	$\sigma_{H\,lim}$ N/mm^2
Through-hardened	Through-hardened	$0,46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0,42\sigma_{B2} + 415$
Carburised, nitrided or induction-hardened	Soft bath nitrided (Tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0,88\,Hv_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

Table 3.3.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,25	1,50

Main propulsion gears for multiple screw	1,20	1,45
Auxiliary gears	1,15	1,40

3.5 Tooth loading for bending stress

3.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}

$$\sigma_F = \frac{F_t}{b m_n} Y_F Y_S Y_\beta K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \text{ N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\,lim} Y_{ST} Y_{\delta\,rel\,T} Y_X}{S_{F\,min} Y_D} \text{ N/mm}^2$$

For values of $S_{F\,min}$, *see Table 3.3.4 Factors of safety*.

For values of $\sigma_{F\,lim}$, *see Table 3.3.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$* .

Stress correction factor Y_{ST} = 2.

Table 3.3.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	0,35 Hv + 125
Gas nitrided	390
Carburized A	450
Carburized B	410
Note 1. A is applicable for Cr Ni Mo carburising steels.	
Note 2. B is applicable for other carburising steels.	

3.5.2 Tooth form factor, Y_F:

$$Y_F = \frac{6\frac{h_F}{m_n}\cos\alpha_{F\,en}}{\left(\frac{S_{Fn}}{m_n}\right)^2 \cos\alpha_n}$$

where

h_F, $\alpha_{F\,en}$ and S_{Fn} are shown in *Figure 3.3.1 Normal tooth section*.

$$\frac{S_{Fn}}{m_n} = z_n \sin\left(\frac{\pi}{3} - v\right) + \sqrt{3}\left(\frac{G}{\cos v} - \frac{P_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n} \tan \nu - H$$

$$G = \frac{r_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4} m_n - h_{ao} tan\ \alpha_n + \frac{S_{pr}}{cos\ \alpha_n} - \left(1 - sin\ \alpha_n\right)\frac{\rho_{ao}}{cos\ \alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in *Figure 3.3.2 External tooth forms*

$$\frac{r_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{cos\ v\left(Z_n cos^2\ v - 2G\right)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_{an}}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi\ d cos\ \beta\ cos\ \alpha_n}{|z|}\left(\varepsilon_{\alpha n} - 1\right)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{\frac{1}{2}}$$

where

$$d_{an} = d_n + d_a - d$$

$$d_n = \frac{d}{cos^2\ \beta_b}$$

$$d_{bn} = d_n \cos \alpha_n$$

$$\epsilon_{\alpha n} = \frac{\varepsilon_\alpha}{cos^2\ \beta_b}$$

$$\gamma_e = \frac{\frac{\pi}{2} + 2 \times tan\ \alpha_n}{z_n} + \text{inv.}\ \alpha_n - \text{inv}\ \alpha_{en}$$

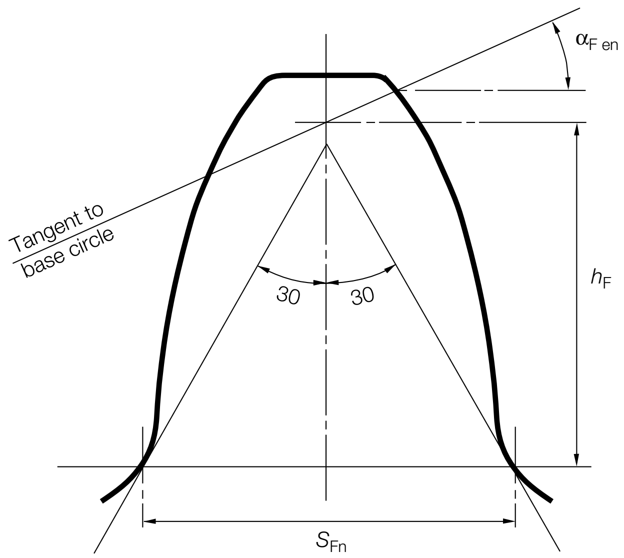
where

$$\alpha_{en} = \text{arc cos}\ \frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[\left(cos\ \gamma_e - sin\ \gamma_e tan\ \alpha_{F\ en}\right)\frac{d_{en}}{m_n} - z_n cos\left(\frac{\pi}{3} - v\right) - \frac{G}{cos\ v} + \frac{r_{ao}}{m_n}\right]$$

where

$$\alpha_{F\ en} = \alpha_{en} - \gamma_e$$



NOTE
For helical gears the normal section is taken with the virtual number of teeth

Figure 3.3.1 Normal tooth section

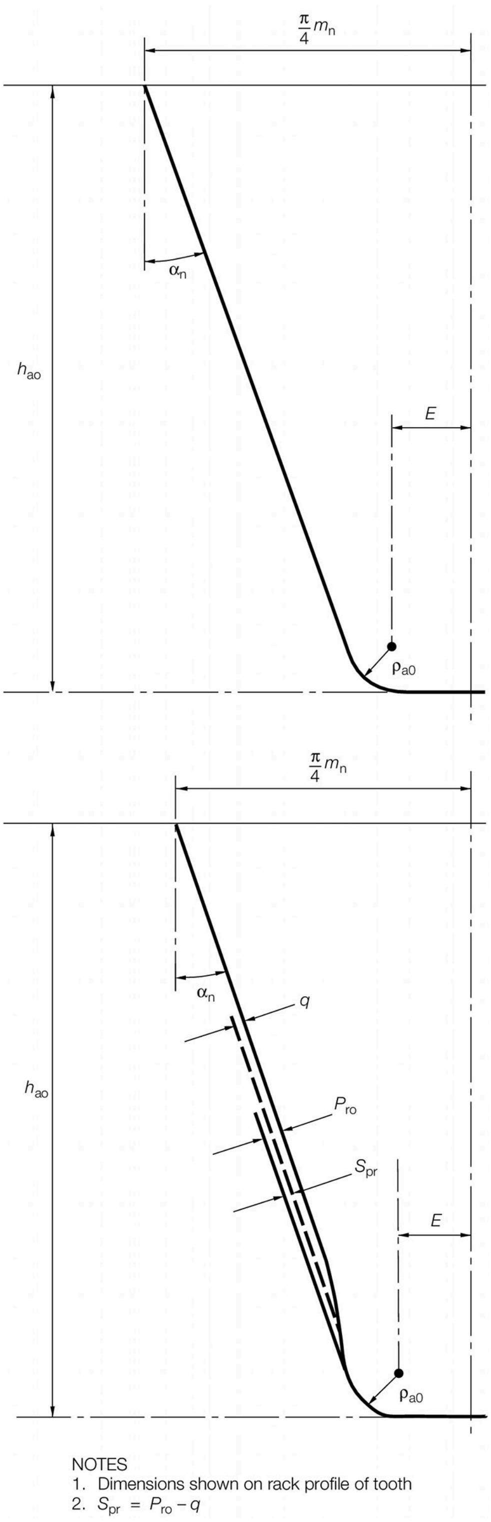


Figure 3.3.2 External tooth forms

3.5.3 For internal tooth forms, the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear.

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + tan\,\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n cos\,\alpha_n}\right) - \frac{\rho_{ao2}}{m_n}cos\frac{\pi}{6}\right]$$, and

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)tan\,\alpha_n\right]tan\,\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - sin\frac{\pi}{6}\right)$$

where

$\alpha_{F\,en}$ is taken as being equal to an

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

3.5.4 Stress concentration factor, Y_s

$$Y_s = (1,2 + 0,13L)q_s^{\left(\frac{1}{1,21 + 2,3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_s = \frac{S_{Fn}}{r}$$

when

$q_s < 1$, the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with α_n = 20° but may be used as an approximation for other pressure angles and internal gears.

3.5.5 Helix angle factor, Y_β

$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right)$, if $\epsilon_\beta > 1$ let $\epsilon_\beta = 1$

but

$Y_b = \geq 1 - 0{,}25\epsilon_\beta \geq 0{,}75$

3.5.6 Relative notch sensitivity factor, $Y_{\delta\,rel\,T}$

$Y_{\delta\,rel\,T} = 1 + 0{,}036\,(q_s - 2{,}5)\left(1 - \frac{\sigma_y}{1200}\right)$ for through-hardened steels

$Y_{\delta\,rel\,T} = 1 + 0{,}008\,(q_s - 2{,}5)$ for carburized and induction-hardened steels, and

$Y_{\delta\,rel\,T} = 1 + 0{,}04\,(q_s - 2{,}5)$ for nitrided steels

3.5.7 Relative surface finish factor, $Y_{R\,rel\,T}$

$Y_{R\,rel\,T} = 1{,}674 - 0{,}529\,(6R_a + 1)^{0{,}1}$ for through-hardened, carburized and induction hardened steels, and

$Y_{R\,rel\,T} = 4{,}299 - 3{,}259\,(6R_a + 1)^{0{,}005}$ for nitrided steels

3.5.8 Size factor, Y_x

$Y_x = 1{,}0$, when $m_n \leq 5$

Y_x = 1,03 – 0,006m_n for through hardened steels

Y_x = 0,85, when $m_n \geq 30$

Y_x = 1,05 – 0,01 m_n for surface-hardened steels

Y_x = 0,80, when $m_n \geq 25$

3.5.9 Design factor, Y_D

Y_D = 0,83 for gears treated with a controlled shot peening process

Y_D = 1,5 for idler gears

Y_D = 1,25 for shrunk on gears, or

Y_D = $1 + \dfrac{0,2 d_s^2 P_r b}{F_t \sigma_{F\,lim}\left(d_f^2 - d_s^2\right)}$, otherwise

Y_D = 1,0.

3.6 Factors of safety

3.6.1 Factors of safety are shown in *Table 3.3.4 Factors of safety*.

3.7 Design of enclosed gear shearing

3.7.1 The following symbols apply:

P in kW and *R* in rpm, *see Pt 5, Ch 1, 3.3 Power ratings 3.3.1*

L = span between shaft bearing centres, in mm

α_n = normal pressure angle at the gear reference diameter, in degrees

β = helix angle at the gear reference diameter, in degrees

d_w = pitch circle diameter of the gear teeth, in mm

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

Note Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts and 1100 N/mm^2 for quill shafts.

3.7.2 This sub-Section is applicable to the main and ancillary transmission shafting, enclosed within the gearcase.

3.7.3 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

d_b = $365\left(\dfrac{PL}{R d_w S_b}\right)^{\frac{1}{3}}\left[1 + \left(\dfrac{tan\,\alpha_n}{cos\,\beta} + \dfrac{tan\,\beta\,d_w}{L}\right)^2\right]^{\frac{1}{6}}$

d_t = $d_t = 365 \times \left(\dfrac{P}{R \times S_s}\right)^{\frac{1}{3}}$

where

s_b = 45 + 0,24(σ_u – 400)

and

$$s_s = 42 + 0{,}09(\sigma_u - 400)$$

3.7.4 For the purposes of the above, it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

3.7.5 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

3.7.6 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is to be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

3.7.7 The diameter of quill shaft (not axially constrained and subject only to external torsional loading) is to be not less than given by the following formula:

Diameter of quill shaft:

$$d_q = 101\sqrt[3]{\frac{P400}{R\sigma_u}}\ mm$$

3.7.8 Where a shaft, located within the gearcase, is subject to the main propulsion thrust, the diameter at the collars of the shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than $1{,}1d_t$. For thrust bearings located outside the gearcase, *see Pt 5, Ch 4 Main Propulsion Shafting*.

3.8 External shafting and components

3.8.1 For shafting external to the gearbox and other components ancillaries, *see Pt 5, Ch 4 Main Propulsion Shafting*.

■ *Section 4* Construction

4.1 Gear wheels and pinions

4.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

4.1.2 Where bolts are used to secure side plates to rim and hub, the bolts are to be a tight fit in the holes and the nuts are to be suitably locked by means other than welding.

4.1.3 Where welding is employed in the construction of wheels, the welding procedure is to be approved by the Surveyor before work is commenced. For this purpose, welding procedure approval tests are to be carried out with satisfactory results. Such tests are to be representative of the joint configuration and materials. Wheels are to be stress relieved after welding. All welds are to have a satisfactory surface finish and contour. Magnetic particle or liquid penetrant examination of all important welded joints is to be carried out to the satisfaction of the Surveyor.

4.1.4 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.2 Accuracy of gear cutting and alignment

4.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated to the satisfaction of the Surveyor. For this purpose, records of measurements should be available for review by the Surveyor on request.

4.2.2 Where allowance has been given for end relief or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

4.3 Gearcases

4.3.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.3.2 For gearcases fabricated by fusion welding the carbon content of steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.3.3 Gearcases are to be stress relief heat treated on completion of all welding.

4.3.4 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.3.5 Gear cases manufactured from material other than steel will be considered upon full details being submitted.

■ *Section 5* **Tests**

5.1 Balance of gear pinions and wheels

5.1.1 All rotating elements, e.g. pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

5.1.2 The permissible residual unbalance, *U*, is defined as follows:

$$U = \frac{60m}{N} \times 10^3 \text{ g mm for } N \leq 3000$$

$$U = \frac{24m}{N} \times 10^3 \text{ g mm for } N > 3000$$

where

m = mass of rotating element, kg

N = maximum service rev/min of the rotating element.

5.1.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance, a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.2 Meshing tests

5.2.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.2.2 The gears are to be suitably coated to demonstrate the contact marking. The marking is to reflect the accuracy grade specified and end relief of helix correction, where these have been applied.

5.2.3 For gears without helix correction, the marking is to be not less than shown in *Table 3.5.1 No load tooth contact marking*.

5.2.4 For gears with end relief of helix correction, the marking is to correspond to the designed no load contact pattern.

Table 3.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	40% h_w for 50% b and 20% h_w for a further 40% b

Q ≥ 6	40% h_w for 35% b and 20% h_w for a further 35% b
Note 1. Where b is face width and h_w is working tooth depth. **Note** 2. For spur gears, the values of h_w should be increased by a further 10%.	

5.2.5 A permanent record is to be made of the meshing contact for purpose of checking the alignment when installed on board ship.

5.2.6 The full load tooth contact marking is to be not less than shown in *Table 3.5.2 Full load tooth contact marking*.

Table 3.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	70% h_w for 60% b and 50% h_w for a further 30% b
Q ≥ 6	60% h_w for 45% b and 40% h_w for a further 35% b
Note 1. Where b is face width and h_w is working tooth depth. **Note** 2. For spur gears, the values of h_w should be increased by a further 10%.	

5.3 Backlash

5.3.1 The normal backlash between any pair of gears should not be less than:

$$\frac{a \cdot \alpha_n}{90\,000} + 0{,}1 \text{ mm}$$

5.3.2 The normal backlash is not to exceed three times the value calculated in *Pt 5, Ch 3, 5.3 Backlash 5.3.1*.

5.4 Alignment

5.4.1 Reduction gears with sleeve bearings, for main and auxiliary purposes, are to be provided with means for checking the internal alignment of the various elements in the gearcases.

5.4.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyor to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board ship.

■

Cross-reference

For lubricating oil systems, *see Pt 5, Ch 12 Machinery Piping Systems*.

■ Scope

The requirements of this Chapter relate, in particular, to formulae for determining the diameters of shafting for main propulsion installations, but requirements for couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included. The diameters may require to be modified as a result of alignment considerations and vibration characteristics, *see Pt 5, Ch 6 Shaft Vibration and Alignment*, or the inclusion of stress raisers, other than those contained in this Chapter.

■ *Section 1* Plans and particulars

1.1 Shafting plans

1.1.1 The following plans, together with the necessary particulars of the machinery, including the maximum power and revolutions per minute, are to be submitted for consideration before the work is commenced:

Thrust shaft

Intermediate shafting

Tube shaft, where applicable

Screwshaft

Screwshaft oil gland

Sternbush.

1.1.2 The specified minimum tensile strength of each shaft is to be stated.

1.1.3 In addition, a shafting arrangement plan indicating the relative position of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, sterntube, ‘A’ bracket and propeller, as applicable, is to be submitted for information.

■ *Section 2* Materials

2.1 Materials for shafts

2.1.1 The specified minimum tensile strength of forgings for shafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel 400 to 760 N/mm^2. *See also Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2*.

(b) Alloy steel not exceeding 800 N/mm^2.

2.1.2 Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.1.3 Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum tensile strength of 500 N/mm^2 .

2.1.4 Where materials with greater specific or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from the formulae used in*Pt 5, Ch 4, 3.2 Intermediate shafts*, *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts*, *Pt 5, Ch 4, 3.5 Hollow shafts* and *Pt 5, Ch 6, 2.5 Limiting stress in propulsion shafting* unless, for intermediate shafts only, it is verified that the materials exhibit a similar fatigue life to conventional steels through compliance with the requirements in *Pt 5, Ch 4, 4 Approval of alloy steel used for intermediate shaft material*.

■ *Section 3* Design

3.1 Fatigue strength analysis

3.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

3.2 Intermediate shafts

3.2.1 The diameter, *d*, of the intermediate shaft is to be not less than determined by the following formula:

$$d = Fk\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

k = 1,0 for shafts with integral coupling flanges complying with *Pt 5, Ch 4, 3.7 Couplings and transitions of diameters* or with shrink fit couplings, *see Pt 5, Ch 4, 3.2 Intermediate shafts 3.2.2*

k = 1,10 for shafts with keyways in tapered or cylindrical connections where the fillet radii in the transverse section of the bottom of the keyway are to be not less than 0,0125d

F = 89 for electric propulsion installations

F = 94 for engine installations

P and *R* are defined in *Pt 5, Ch 1, 3.3 Power ratings* (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the material, in N/mm^2, *see Pt 5, Ch 4, 2.1 Materials for shafts 2.1.3*

After a length of 0,2*d* from the end of a keyway the diameter of the shaft may be gradually reduced to that determined with *k* = 1,0.

3.2.2 For shrink fit couplings k refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 per cent and a blending radius as described in *Pt 5, Ch 4, 3.7 Couplings and transitions of diameters 3.7.7*.

3.2.3 Keyways are in general not to be used in installations with a barred speed range.

3.2.4 For shafts with design features other than stated as above, the value of *k* will be specially considered.

3.2.5 Carbon-manganese steel intermediate shafts having flanges attached by fusion welding may be accepted provided that the following conditions are complied with:

(a) The materials are of a weldable quality with a carbon content generally not exceeding 0,23 per cent and the carbon equivalent not exceeding 0,4 per cent.
(b) The weld is of a full penetration type.
(c) Welding is to be in accordance with an LR approved procedure.
(d) The welding is carried out by qualified welders.
(e) The shaft fillet radius and flange are machined all over. Particular attention is to be paid to the smooth blending of the fillet radius.
(f) The welds are subsequently examined by magnetic crack detection methods all to the Surveyor's satisfaction.
(g) The shaft is to be post-weld heat treated at a temperature of 650°C with a holding time of one hour per 25 mm of weld thickness and thereafter allowing the structure to cool slowly in the furnace.
(h) The whole of the work is carried out to the Surveyor's satisfaction.

For a typical example of this type of coupling, *see Figure 4.3.1 Typical example of coupling welded to intermediate shaft*. Alternative methods of attaching the coupling flanges to intermediate shafts will be specially considered.

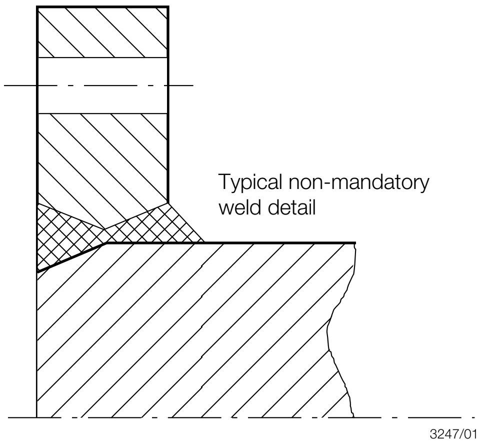


Figure 4.3.1 Typical example of coupling welded to intermediate shaft

3.3 Thrust shafts and thrust shaft bearing arrangements

3.3.1 Thrust shafts and thrust shaft bearing arrangements situated outside the gearbox or engine, with collar block arrangements or axial roller thrust bearings, will be specially considered. For thrust shafts inside the gearbox, *see Pt 5, Ch 3, 3.7 Design of enclosed gear shearing 3.7.8*.

3.4 Screw shafts and tube shafts

3.4.1 For screw shafts and tube shafts, (i.e. the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel and protected by approved oil sealing glands, the requirements of *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2* to *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.5* are applicable.

3.4.2 The diameter, d_{p} of the protected screw shaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screw shaft flange, is to be not less than determined by the following formula:

$$d = 94k\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_{\text{u}}+160}\right)}\ \text{mm}$$

where

k = 1,22 for a shaft carrying a keyless propeller fitted on a taper, or where the propeller is attached to an integral flange, and where the shaft is oil lubricated and provided with an approved type of oil sealing gland

where

= 1,26 for a shaft carrying a keyed propeller and where the shaft is oil lubricated and provided with an approved type of oil sealing gland

= *P* and *R* are defined in *Pt 5, Ch 1, 3.3 Power ratings* (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2. *See Pt 5, Ch 4, 2.1 Materials for shafts 2.1.3*.

3.4.3 The diameter, d_p of the screw shaft determined in accordance with the formula in *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2* is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_p whichever is the greater.

3.4.4 The diameter of the portion of the screw shaft and tube shaft, forward of the length required by *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2* to the forward end of the forward sterntube seal, is to be determined in accordance with the formula in *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2* with a *k* value of 1,15. The change of diameter from that determined with *k* = 1,22 or 1,26 to that determined with *k* = 1,15 should be gradual, *see Pt 5, Ch 4, 3.7 Couplings and transitions of diameters*.

3.4.5 Screw shafts which run in sterntubes and tube shafts may have the diameter forward of the forward sterntube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screw shaft/tube shaft to intermediate shaft couplings are to be avoided, *see Pt 5, Ch 4, 3.7 Couplings and transitions of diameters*.

3.4.6 The diameter of unprotected screw shafts and tube shafts of materials having properties as shown in *Table 4.3.1 Provisional 'A' value for use in unprotected screw shaft formula* is to be not less than:

$$d_{\mathbf{up}} = 128 A \sqrt[3]{\frac{P}{R}}$$

where '*A*' is taken from *Table 4.3.1 Provisional 'A' value for use in unprotected screw shaft formula*.

Table 4.3.1 Provisional 'A' value for use in unprotected screw shaft formula

Material	‘A' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Nickel/aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

3.4.7 For shafts of non-corrosion-resistant materials which are exposed to outboard water, the diameter of the shaft is to be determined in accordance with the formula in *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2* with a *k* value of 1,26 and σ_u taken as 400 N/mm^2.

3.4.8 The diameter of the unprotected screw shaft forward of the stern seal need not be greater than the diameter as required by *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.5*.

3.5 Hollow shafts

3.5.1 Where the thrust, intermediate, tube shafts and screw shafts have central holes, having a diameter greater than 0,4 times the outside diameter, the equivalent diameter d_e of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

d_e =

$$= d_o \sqrt[3]{1 + \left(\frac{d_i}{d_o}\right)^4}$$

$$= d_o \sqrt[3]{1 + \left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole, in mm.

3.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

3.6 Cardan shafts

3.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare coupling is to be provided on board.

3.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

3.7 Couplings and transitions of diameters

3.7.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by *Pt 5, Ch 4, 3.8 Coupling bolts 3.8.1*, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate shafts, thrust shafts and the inboard end of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by *Pt 5, Ch 4, 3.2 Intermediate shafts*.

3.7.2 The fillet radius at the base of the coupling flange is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nuts and bolt heads.

3.7.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

3.7.4 All couplings which are attached to shafts are to be of approved dimensions.

3.7.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

3.7.6 Where a coupling is shrunk onto the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, full particulars of the coupling including the interference fit are to be submitted for special consideration.

3.7.7 Transitions of diameters are to be designed with either a smooth taper or a blending radius. In general a blending radius equal to the change in diameter is recommended.

3.8 Coupling bolts

3.8.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{212\ 10^6 P}{n\ D\ \sigma_u R}}\ \text{mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P and *R* are as defined in *Pt 5, Ch 1, 3.3 Power ratings*.

3.8.2 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of *Pt 5, Ch 4, 3.8 Coupling bolts 3.8.1*. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned in accordance with manufacturer's instructions.

3.8.3 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1,348\sqrt{\left[\frac{120\ 10^6 FP(1+C)}{RD} + Q\right]\frac{1}{n\ \sigma_y}}$$

where

d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P and *R* are defined in*Pt 5, Ch 1, 3.3 Power ratings*.

F = 2,5 where the flange connection is not accessible from within the ship or vessel

= 2,0 where the flange connection is accessible from within the ship or vessel

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

3.8.4 Consideration will be given to those arrangements where the bolts are pre-tensioned to loads other than 70 per cent of the material yield strength.

3.8.5 Where clamp bolts are fitted they are to comply with the requirements of *Pt 5, Ch 4, 3.8 Coupling bolts 3.8.3* and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

3.9 Keys and keyways for propeller connections

3.9.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

3.9.2 For sled-runner ended keys at least one screwed pin is to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled.

3.9.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

3.9.4 The effective sectional area of the key in shear, is to be not less than:

$$A = \frac{155\, d^3}{\sigma_u d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with *Pt 5, Ch 4, 3.2 Intermediate shafts*, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

3.9.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$A = \frac{23d^3}{\sigma_y d_1}\ \text{mm}^2$$

where

σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

3.10 Keys and keyways for inboard shaft connections

3.10.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

3.10.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126d^3}{\sigma_u d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with *Pt 5, Ch 4, 3.2 Intermediate shafts*, based on material having a specified minimum tensile strength of 400 N/mm^2 and k= 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

3.10.3 For the effective area in crushing of key, shaft or boss *see Pt 5, Ch 4, 3.9 Keys and keyways for propeller connections 3.9.5*. Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

3.11 Interference fit assemblies

3.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

Note

For guidance purposes only,

T_{max} = T_{mean} (1 + C)

where

C = is to be taken from *Table 4.3.2 'C' values for guidance purposes*

S = 2,0 for assemblies accessible from within the vessel

= 2,5 for assemblies not accessible from within the vessel.

Table 4.3.2 '*C*' values for guidance purposes

Coupling location	*C*
High speed shafting – I.C. engine driven	0,3
High speed shafting Electric motor driven	0,1
Low speed shafting – main or PTO stage gearing	0,1

3.11.2 The effect of any axial load acting on the assembly is to be considered.

3.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

3.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

3.12 Sternbushes and sterntube arrangement

3.12.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.
(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resinthickness of 12 mm.
(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.

3.12.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with ligum vitae, rubber composition or staves of synthetic material, the length is to be not less than 4,0 times the rule diameter of the screwshaft in way of the bearing.
(b) For water lubricated bearings lined with two or more circumferentially spaced sectors or synthetic material, in which it can be shown that the sectors operate on hydrodynamic principles, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 MPa. The length of the bearing is to be not less than 2,0 times the rule diameter of the shaft in way of the bearing.
(c) For oil lubricated bearings of synthetic material the length of the bearing is, in general, to be not less than 2,0 times the rule diameter of the shaft in way of the bearing. The nominal bearing pressure is not to exceed the maximum for which the synthetic material has been approved
(d) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately 2,0 tmes the rule diameter of the shaft in way of the beairng and is to be such that the nominal bearing pressure will not exceed 0,8 MPa. The length of the bearing is to be not less than 1,5 times its diameter.
(e) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than 4,0 times the rule diameter of the shaft in way of the bearing.
(f) For bearings which are grease lubricated, the length of the bearing is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing. Other lengths may be considered upon application, subject to the provision of suitable supporting in-service or testing evidence at relevant shaft pressures and velocities.

3.12.3 Synthetic materials for application as stern tube bearings are to be approved in accordance with *Rules for the Manufacture, Testing and Certification of Materials, July 2022, Ch 14, 2.13 Sterntube bearings*

3.12.4 Sternbushes are to adequately secured in housings.

3.12.5 Forced water lubrication is to be provided for all bearings lined with rubber or synthetic material. The supply of water may come from a circulating pump or other pressure source. Flow indicators with an alarm in the wheelhouse are to be provided for the water service to the bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of synthetic material.

3.12.6 For forced water lubricating systems an alarm is to be provided in the wheelhouse for pump failure. *See Pt 6, Ch 1 Control Engineering Systems*.

3.12.7 Bearings of synthetic material are to be supplied finished machined to design dimensions within a rigid bush. Means are to be provided to prevent rotation of the lining within the bush during operation.

3.12.8 The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

3.12.9 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the engine room.

3.12.10 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means.

3.12.11 For oil lubricated bearings of synthetic material, the flow of lubricant is to be such that overheating, under normal operating conditions, cannot occur.

3.12.12 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all water temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oil tightness between the sterntube and the propeller boss.

3.12.13 Water sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all water temperatures in the proposed area of operation. Two independent sealing glands are to be provided or alternatively one sealing gland capable of being replaced when the ship is afloat.

3.13 Vibration and alignment

3.13.1 For the requirements for shaft vibration and alignment, *see Pt 5, Ch 6 Shaft Vibration and Alignment*.

■ *Section 4*
Approval of alloy steel used for intermediate shaft material

4.1 Application

4.1.1 The requirements of *Pt 5, Ch 4, 4 Approval of alloy steel used for intermediate shaft material* are, in addition to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*, *Ch 5, 3 Forgings for shafting and machinery*, to be applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm2, but, not exceeding 950 N/mm2 intended for use as intermediate shaft material.

4.2 Torsional fatigue test

4.2.1 A torsional fatigue test is to be performed to verify that the material exhibits a similar fatigue life to conventional steels. The torsional fatigue strength of the material is to be equal to or greater than the permissible torsional vibration stress τ_C given by the formulae in *Pt 5, Ch 6, 2.5 Limiting stress in propulsion shafting*.

4.2.2 The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor β should be evaluated in consideration of the severest torsional stress concentration factor in the design criteria.

4.2.3 Test procedures are to be in accordance with Section 10 of ISO 1352 and the test conditions applied are to be in accordance with *Table 4.4.1 Test Condition*. Mean surface roughness is to be less than 0,2µm Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352.

Table 4.4.1 Test Condition

Loading type	Torsion
Stress ratio	R = -1
Load waveform	Constant amplitude sinusoidal

Evaluation	S-N curve
Number of cycles for test termination	1 x 10^7

4.2.4 The measured torsional fatigue strength for continuous operation, τ_c, and torsional fatigue strength for transient operation, τ_t, are to be equal to or greater than the values given by the following formulae:

$$\tau_c \geq \frac{\sigma_u + 160}{6} \cdot C_k \cdot C_d \quad \text{for} \quad r = 0$$

$$\tau_t \geq 1,7 \cdot \tau_c \cdot \frac{1}{\sqrt{C_k}}$$

where

C_k = a factor for different shaft design features, *see Table 6.2.1 C k factors* , *Pt 5, Ch 6, 2.4 Symbols and definitions 2.4.4*

C_d = size factor, *see Pt 5, Ch 6, 2.4 Symbols and definitions 2.4.1*

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

r = speed ratio, N/N_s, *see Pt 5, Ch 6, 2.4 Symbols and definitions 2.4.1*

4.3 Material requirements

4.3.1 The steels are to have a degree of cleanliness as shown in *Table 4.4.2 Cleanliness requirements* when tested according to ISO 4967 method A. Representative samples are to be obtained from each heat of forged or rolled products.

Table 4.4.2 Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index I
Type A	Fine	1
	Thick	1
Type B	Fine	1,5
	Thick	1
Type C	Fine	1
	Thick	1
Type D	Fine	1
	Thick	1
Type DS	-	1

Section 1
Plans and particulars

1.1 Details to be submitted

1.1.1 A plan, in triplicate, of the propeller is to be submitted for approval, together with the following particulars using the symbols shown:

(a) Maximum blade thickness of the expanded cylindrical section considered, T, in mm.
(b) Maximum shaft power (*see Pt 5, Ch 1, 3.3 Power ratings*), P, in kW.
(c) Estimated ship speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see* (*Pt 5, Ch 5, 1.1 Details to be submitted 1.1.1.(b)*) and (*Pt 5, Ch 5, 1.1 Details to be submitted 1.1.1.(d)*)).
(d) Revolutions per minute of the propeller at maximum power, R.
(e) Propeller diameter, D, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius $P_{0,6}$, in metres
(i) Pitch at 70 per cent radius $P_{0,7}$, in metres
(j) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(k) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only) $L_{0,35}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(m) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), A, in mm.
(n) Number of blades, N.
(o) Developed area ratio, B.
(p) Material: type and specified minimum tensile strength.
(q) θ_s, skew angle, in degrees, (*see Figure 5.1.1 Definition of skew angle*).
(r) Connection of propeller to shaft – details of fit, push-up, securing, etc.

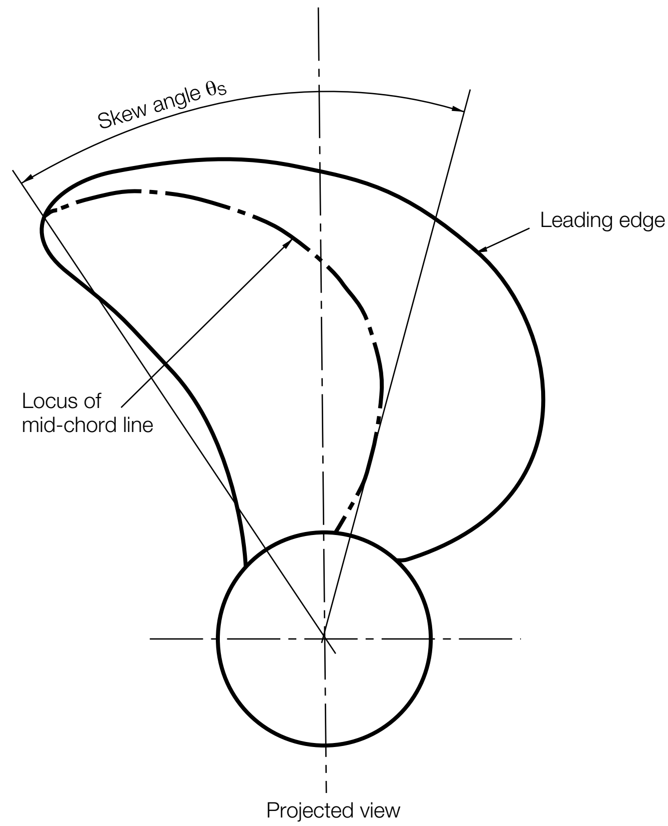


Figure 5.1.1 Definition of skew angle

1.1.2 For propellers having a skew angle equal to or greater than 50°, in addition to the particulars detailed in *Pt 5, Ch 5, 1.1 Details to be submitted 1.1.1* details are to be submitted of:

(a) Full blade section details at each radial station defined for manufacture.

(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:

(i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.

(ii) Section pressure distributions calculated by either an advised inviscid or viscous procedure.

1.1.3 For blades of fixed pitch propellers with skew angle of 30° or greater, the stresses in the propeller blade during astern operation are not to exceed 80 per cent of the propeller blade material proof stress. Consideration is to be given to failure conditions and a factor of safety of 1,5 is to be attained using an acceptable fatigue failure criteria. Documentary evidence confirming that these criteria are satisfied is to be submitted.

1.1.4 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see Figure 5.1.1 Definition of skew angle*.

1.1.5 Where it is proposed to fit the propeller to the screwshaft without the use of a key, plans of the boss, tapered end of screw shaft and propeller nut are to be submitted.

Section 2
Materials

2.1 Castings

2.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials*. The specified minimum tensile strength is to be not less than stated in *Table 5.2.1 Materials for propellers*.

Table 5.2.1 Materials for propellers

Material	SI units			Metric units		
	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2
Grey cast iron	250	7,2	17,2	25	7,2	1,75
Spheroidal or nodular graphite cast iron	400	7,3	20,6	41	7,3	2,1
Carbon steels	400	7,9	20,6	41	7,9	2,1
Low alloy steels	440	7,9	20,6	45	7,9	2,1
13% chromium stainless steels	540	7,7	41	55	7,7	4,2
Chromium-nickel austenitic stainless steel	450	7,9	41	46	7,9	4,2
Duplex stainless steels	590	7,8	41	60	7,8	4,2
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56	60	7,6	5,7
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46	64	7,5	4,7

2.1.2 Where it is proposed to use materials which are not included in *Table 5.2.1 Materials for propellers*, details of the chemical composition, mechanical properties and density are to be submitted for approval.

Section 3
Design

3.1 Minimum blade thickness

3.1.1 For propellers having a skew angle of less than 25° as defined in *Pt 5, Ch 5, 1.1 Details to be submitted 1.1.3* the minimum blade thickness, *T*, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 95\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

K = $\dfrac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see Table 5.2.1 Materials for propellers*

U = allowable stress, in N/mm^2 *see Pt 5, Ch 5, 3.1 Minimum blade thickness 3.1.2*, *Pt 5, Ch 5, 3.1 Minimum blade thickness 3.1.3*, *Pt 5, Ch 5, 3.1 Minimum blade thickness 3.1.4*, and *Table 5.2.1 Materials for propellers*

E = $\dfrac{\text{actual face modulus}}{0,09T^2L}$

For aerofoil sections with and without trailing edge washback, *E* may be taken as 1,0 and 1,25 respectively

$$\left.\begin{aligned} C &= 1,0 \\ F &= \frac{p_{0,25}}{D} + 0,8 \\ M &= 1,0 + \frac{3,75D}{P_{0,7}} + 2,8\frac{P_{0,25}}{D} \end{aligned}\right\} \text{for solid propellers at 25 per cent radius}$$

$$\left.\begin{aligned} C &= 1,4 \\ F &= \frac{p_{0,35}}{D} + 1,6 \\ M &= 1,35 + \frac{5D}{P_{0,7}} + 2,6\frac{P_{0,35}}{D} \end{aligned}\right\} \text{for controllable pitch propellers at 35 per cent radius}$$

$$\left.\begin{aligned} C &= 1,6 \\ F &= \frac{p_{0,6}}{D} + 4,5 \\ M &= 1,35 + \frac{5D}{P_{0,7}} + 1,35\frac{P_{0,6}}{D} \end{aligned}\right\} \text{for all propellers at 60 per cent radius}$$

3.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of

U is to be multiplied by $\left(\frac{r}{T}\right)^{0,2}$

where

r = proposed fillet radius at the root, in mm

T = proposed fillet radius at the root, in mm

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm.

3.1.3 For propellers having skew angles of 25° or greater, but less than 50°, the mid-chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0,54 T_{0,6} \sqrt{1 + 0,1\,\theta_s} \text{ mm}$$

The mid-chord thickness, $T_{sk\ root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\ root} = 0,75 T_{root} \sqrt[4]{1 + 0,1\theta_s} \quad \text{mm}$$

θ_s = proposed skew angle as defined in *Pt 5, Ch 5, 1.1 Details to be submitted 1.1.4*

$T0,6$ = thickness at 60 per cent radius calculated by *Pt 5, Ch 5, 3.1 Minimum blade thickness 3.1.1*, in mm

T_{root} = thickness at 25 per cent or 35 per cent calculated by *Pt 5, Ch 5, 3.1 Minimum blade thickness 3.1.1*, in mm

The thicknesses at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

3.1.4 Results of detailed calculations where carried out, are to be submitted.

3.1.5 For cases where the composition of the propeller material is not specified in *Table 5.2.1 Materials for propellers*, or where propellers of the cast irons and carbon and low alloy steels shown in this Table are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

3.1.6 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw ships.

3.1.7 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by *Pt 5, Ch 5, 3.1 Minimum blade thickness 3.1.1* or *Pt 5, Ch 5, 3.1 Minimum blade thickness 3.1.3*, a detailed stress computation for the blades is to be submitted for consideration.

3.2 Keyless propellers

3.2.1 The symbols used in *Pt 5, Ch 5, 3.2 Keyless propellers 3.2.2* are defined as follows:

d_1 = diameter of the screw shaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its midlength, in mm.

d_i = bore diameter of screw shaft, in mm

k_3 = d_3 / d_1

I = d_i / d_1

$$P_1 = \frac{2M}{A_1 \theta_1 V_1}\left[-1 + \sqrt{1 + V_1\left(\frac{F_1^2}{M^2} + 1\right)}\right]$$

$$P_{10} = \frac{2M}{A_1 \theta_1 V_1} - 1 + \sqrt{1 + V_1 \frac{F_{10}^2}{M^2} + 1}$$

A_1 = contact area of fitting at screw shaft, in mm^2

B_3 = $\dfrac{1}{E_3}\left(\dfrac{k^2{}_3+1}{k^2{}_3-1}+\nu_3\right)+\dfrac{1}{E_1}\left(\dfrac{1+l^2}{1-l^2}-\nu_1\right)$

C = 0 for turbine installations

= $\dfrac{\text{vibratory torque at the maximum service speed}}{\text{mean torque at the maximum service speed}}$ for engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

F_1 = $\dfrac{2000Q}{d_1}(1+C)$

F_{10} = $\dfrac{2Q}{d_1}\left(1+C+\dfrac{I_f}{100}\right)$

I_f = percentage increase for Ice Class obtained from *Pt 5, Ch 7 Strengthening for Navigation in Ice*

M = propeller thrust, in *N*

Q = mean torque corresponding to *P* and *R* as defined in *Pt 5, Ch 1, 3.3 Power ratings*, in Nmm

T_1 = temperature at time of fitting propeller on shaft, in °C

V_1 = $0{,}51\left(\dfrac{\mu_1}{\theta_1}\right)^2-1$

α_1 = coefficient of linear expansion of screw shaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\dfrac{1}{15}$ on the diameter, i.e. $\theta_1 \leq \dfrac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screw shaft material

ν_3 = Poisson's ratio for propeller material

Consistent sets of units are to be used in all formulae.

3.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta_T = \frac{d_1}{\theta_1}\left(p_1 B_3 + (\alpha_3 - \alpha_1)(35 - T_1)\right) \text{ mm}$$

or, where Ice Class notation is required, the greater of δ_T or δ_O, where

$$\delta_O = \frac{d_1}{\theta_1}\left(p_{10}B_3 - (\alpha_3 - \alpha_1)(35 - T_1)\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_o of the propeller material is to be not less than:

$$\sigma_O = \frac{1,4}{B_3}\left(\frac{\theta_1 \delta_p}{d_1} + T_1(\alpha_3 - \alpha_1)\right)\frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature.

The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0,002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}(\alpha_3 - \alpha_1)\right) \text{ N}$$

3.3 Keyed propellers pushed up by an hydraulic nut

3.3.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of frettage a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved and the requirements of *Pt 5, Ch 5, 4.2 Shop test of keyless propellers* and *Pt 5, Ch 5, 4.3 Final fitting of keyless propellers*, where appropriate, are applicable.

■ *Section 4* Fitting of propellers

4.1 Propeller boss

4.1.1 The propeller boss is to be a good fit on the screwshaft cone. The forward edge of the bore of the propeller boss is to be rounded to a radius of not less than 6 mm. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

4.2 Shop test of keyless propellers

4.2.1 The bedding of the propeller with the shaft, is to be demonstrated in the shop to the satisfaction of the Surveyors. Sufficient time is to be allowed for the temperature of the components to equalize before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

4.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

4.3 Final fitting of keyless propellers

4.3.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft to the satisfaction of the Surveyors. The propeller nut is to be securely locked to the shaft.

4.3.2 Permanent reference marks are to be made on the propeller boss, nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimize stress raising effects.

4.3.3 The outside of the propeller boss is to be hard stamped with the following details:

(a) For the oil injection method of fitting, the start point load and the axial pull-up at 0°C and 35°C.
(b) For the dry fitting method, the push-up load at 0°C and 35°C.

4.3.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

■ Scope

The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by engines or electric motors, directly driven or geared to the shafting, developing 500 kW and over, unless otherwise stated.
(b) Machinery driven at constant speed by oil engines, developing 500 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

Unless otherwise advised, it is the responsibility of the Shipbuilder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

■ *Section 1* General

1.1 Basic requirements

1.1.1 The systems are to be free from excessive torsional, axial, lateral and linear vibration, and are to be aligned in accordance with accepted tolerances and taking into account the requirements of *Pt 5, Ch 6, 5.5 Measurements*.

1.1.2 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values such as stiffness and damping of flexible couplings and dampers or engine misfire conditions.

1.1.3 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

1.1.4 Where significant changes are subsequently made to a dynamic system which has been approved (e.g. by changing the original design parameters of the prime movers and/or propulsion shafting system or by fitting a propeller or flexible coupling of different design from the previous), revised calculations may require to be submitted for consideration. Details of all such changes are to be submitted.

1.2 Resilient mountings

1.2.1 For resilient mountings, *see Pt 5, Ch 1, 4.2 Machinery fastenings*.

Section 2
Torsional vibration

2.1 General

2.1.1 In addition to the shafting complying with the requirements of *Pt 5, Ch 1 General Requirements for the Design and Construction of Machinery* to *Pt 5, Ch 5 Propellers*,*Pt 5, Ch 16 Azimuth Thrusters* and *Pt 5, Ch 17 Steerable Bow Thrusters* (where applicable), approval is also dependent on the torsional vibration characteristics of the complete shafting system(s) being found satisfactory.

2.2 Particulars to be submitted

2.2.1 Torsional vibration calculations, showing the mass elastic values, associated natural frequencies and an analysis of the vibratory torques and stresses for the full dynamic system.

2.2.2 Particulars of the division of power and utilisation, throughout the speed range, for multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.2.3 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, range of trawling revolutions per minute, combinator characteristics for installations equipped with controllable pitch propellers.

2.2.4 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.2.5 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with manufacturer's estimates of mass moment of inertia for the rotating parts.

2.2.6 Details of vibration or performance monitoring proposals where required.

2.3 Scope of calculations

2.3.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the engines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.3.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.3.3 The calculations carried out on engine systems are to be based on the Enginebuilder's harmonic torque data. The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing. Calculations are also to take account of a degree of imbalance between cylinders, which is characteristic of the normal operation of an engine under service conditions.

2.3.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.3.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller excitation data for the installation should be used as a basis for calculation, and submitted.

2.3.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

2.4 Symbols and definitions

2.4.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm

d_i = diameter of internal bore, in mm

k = the factor used in determining minimum shaft diameter, defined in *Pt 5, Ch 4, 3.2 Intermediate shafts 3.2.1* and *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2*

r = ratio N/N_s or N_c/N_s whichever is applicable

C_d = a size factor defined as 0,35 + 0,93$d^{-0,2}$

C_k = a factor for different shaft design features, *see Table 6.2.1 C k factors*

N = engine speed, in rev/min

N_c = critical speed, in rev/min

N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min

Q_s = rated full load mean torque, kNm

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

τ_c = permissible stress due to torsional vibrations for continuous operation, in N/mm^2

τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2

e = slow width, in mm.

l = slot length, in mm.

2.4.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

2.4.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

2.4.4 For a longitudinal slot, C_k = 0,3 is applicable within the dimension limitations given in *Pt 5, Ch 6, 3.1 Intermediate shafts 3.1.6* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). If the slot dimensions are outside these limitations, or if the use of an other C_k is desired, the actual stress concentration factor (scf) is to be documented or determined from *Pt 5, Ch 6, 2.4 Symbols and definitions 2.4.5*, in which case:

$$C_K = \frac{145}{scf}$$

Note The *scf* is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).

Table 6.2.1 C_k factors

Intermediate shafts with						Thrust shafts external to engines		Propeller shafts		
Integral coupling flanges and straight sections	Shrink-fit coupling	Keyway,tapered connection	Keyway, cylindrical connection	Radial hole	Longitudinal slot	On both sides of thrust collar	In way of axial bearing where a roller bearing is used as a thrust bearing	Flange mounted or keyless tapered fitted propellers	Key fitted propellers	Between forward end of aft most bearing and forward sterntube seal

1,0	1,0	0,60	0,45	0,50	0,30 (*see* 2.4.4)	0,85	0,85	0,55	0,55	0,80
Note The determination of *C*k factors for shafts other than shown in this Table will be specially considered by LR.										

2.4.5 **Stress concentration factor of slots.** The stress concentration factor (*scf*) at the end of the slots can be determined by means of the following empirical formulae:

$$scf = \alpha_t (hole) + 0{,}8 \times \frac{\frac{(l-e)}{d}}{\sqrt{\left(1 - \frac{d_i}{d}\right) \times \frac{e}{d}}}$$

This formula applies to:

- Slots at 120 or 180 or 360 degrees apart
- Slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- Slots with no edge rounding (except chamfering), as any edge rounding increases the *scf* slightly

α_t (*hole*) represents the stress concentration of radial holes and can be determined as:

$$\alpha_t (\text{hole}) = 2{,}3 - 3 \times \frac{e}{d} + 15 \times \left(\frac{e}{d}\right)^2 + 10 \times \left(\frac{e}{d}\right)^2 \times \left(\frac{d_i}{d}\right)^2$$

where

e = hole diameter, in mm or simplified to α_t (*hole*) = 2,3.

2.5 Limiting stress in propulsion shafting

2.5.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from outboard water. For screwshafts, the limits apply to the minimum sections of the portions of the screwshaft as defined in *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts*.

2.5.2 In the case of unprotected screwshafts, special consideration will be given.

2.5.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d \left(3 - 2r^2\right) \text{ for } r < 0{,}9 \text{ N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d 1{,}38 \text{ for } 0{,}9 \le r \le 1{,}05 \text{ N/mm}^2$$

$$\tau_t = \pm 1{,}7 \tau_c \frac{1}{\sqrt{C_k}} \text{ for } r \le 0{,}8 \text{ N/mm}^2$$

2.5.4 In general, the tensile strength of the steel used is to comply with the requirements of *Pt 5, Ch 4, 2 Materials*. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of alloy steel intermediate shafts, or 600 N/mm^2 in the case of carbon-manganese steel intermediate thrust and propeller shafts unless, for intermediate shafts only, it is verified that the materials exhibit a similar fatigue life to conventional steels through compliance with the requirements in *Pt 5, Ch 4, 4 Approval of alloy steel used for intermediate shaft material*.

2.5.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

2.6 Generator sets

2.6.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

2.6.2 Within the speed limits of 0,95N_s and 1,05N_s the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm(21 - 0{,}014d) \text{ N/mm}^2$$

2.6.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$$\tau_t = 5{,}5\tau_c \text{ N/mm}^2$$

2.6.4 The amplitudes of the total vibratory inertia torques imposed on the generator rotors are to be limited to ±2,0Q_s in general, or to ±2,5Q_s for close-coupled revolving field alternating current generators, over the speed range from 0,95N_s to 1,05N_s. Below 0,95N_s the amplitudes are to be limited to ± 6,0Q_s. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

2.6.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

2.6.6 In addition to withstanding the vibratory conditions over the speed range from 0,95N_s to 1,05N_s flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

2.6.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in *Pt 5, Ch 6, 2.3 Scope of calculations 2.3.3*.

2.7 Other auxiliary machinery systems

2.7.1 The relevant requirements of*Pt 5, Ch 6, 2.6 Generator sets 2.6.1*, *Pt 5, Ch 6, 2.6 Generator sets 2.6.2* and *Pt 5, Ch 6, 2.6 Generator sets 2.6.3*are also applicable to other machinery installations such as pumps or compressors with the speed limits being taken as 0,95N_s to 1,10N_s.

2.8 Other machinery components

2.8.1 **Torsional vibration dampers.** The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between 0,85N_s and 1,05N_s are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

2.8.2 **Flexible couplings:**

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the maker's recommended limits for angular amplitude or heat dissipation.
(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

2.8.3 **Gearing:**

(a) The torsional vibration characteristics are to comply with the requirements of *Pt 5, Ch 6, 2.3 Scope of calculations*. The sum of the mean and of the vibratory torque should not exceed four-thirds of the full transmission torque, at MCR, throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given to the acceptance of additional vibratory loading on the gears.
(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

2.9 Measurements

2.9.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges, and the confirmation of their limits.

2.9.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

2.9.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limiting stresses as defined in *Pt 5, Ch 6, 2.5 Limiting stress in propulsion shafting*, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

2.10 Vibration monitoring

2.10.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

2.11 Restricted speed and/or power ranges

2.11.1 Restricted speed and/or power ranges will be imposed to cover all speeds where the stresses exceed the limiting values, τ_C, for continuous running, including one-cylinder misfiring conditions if intended to be continuously operated under such conditions. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions are to be considered. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items. At each end of the restricted speed range the engine is to be stable in operation.

2.11.2 The restricted speed range is to take account of the tachometer speed tolerances at the barred speeds.

2.11.3 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at r = 0,8 the stress due to the upper flank does not exceed τ_c.

2.11.4 Provided that the stress amplitudes due to a torsional critical response at the borders of the barred speed range are less than τ_C under normal and stable operating conditions the speed restriction derived from the following formula may be applied:

$$\frac{16}{18-r}N_c \text{ to } \frac{18-r}{16}N_c \text{ inclusive}$$

2.11.5 Where calculated vibration stresses due to criticals below 0,8N_s marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

2.11.6 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured vibration stresses are in excess of τ_c, having regard to the tachometer accuracy.

2.11.7 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

2.11.8 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

2.11.9 For excessive vibratory torque, stress or amplitude in other components, based on *Pt 5, Ch 6, 2.8 Other machinery components 2.8.1*, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

2.11.10 Where restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

2.11.11 Restricted speed ranges in one-cylinder misfiring conditions on ships with single engine propulsion are to enable safe navigation whereby sufficient propulsion power is available to maintain control of the ship.

2.11.12 There are to be no restricted speed ranges imposed above a speed ratio of r = 0,8 under normal operating conditions.

2.12 Tachometer accuracy

2.12.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyor to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

2.13 Governor control

2.13.1 Where there is a significant critical response above and close to service speed, consideration is to be given to the effect of temporary overspeed.

■ *Section 3* Axial vibration

3.1 General

3.1.1 For all main propulsion shafting systems, the Shipbuilders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

3.2 Particulars to be submitted

3.2.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

3.2.2 Engine Builder's recommendation for axial vibration amplitude limits at the non-driving end of the crankshaft or at the thrust collar.

3.2.3 Estimate of flexibility of the thrust bearing and its supporting structure.

3.2.4 The requirement for calculations to be submitted may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted.

3.3 Calculations

3.3.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.
(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

3.3.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

3.3.3 For those systems as defined in *Pt 5, Ch 6, 3.3 Calculations 3.3.1*, the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$n_{\text{c}} = \frac{0,98}{N}\left(\frac{ab}{a+b}\right)^{\frac{1}{2}} \text{(rev/min)}$$

where

$a = \dfrac{E}{Gl^2}(66,2 + 97,5A - 8,88A^2)^2$ (c/min)^2

$b = 91,2\,\dfrac{k}{M_{\text{e}}}$ (c/min)^2

d = internal diameter of shaft, in mm

k = estimated stiffness at thrust block bearing, in N/m

where

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg

= $0{,}785\,(D^2 - d^2)\,Gl$

n_c = propeller speed at which critical frequency occurs, in rev/min

$A = \dfrac{m}{M}$

D = outside diameter of shaft, taken as an average over length, l, in mm

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

M = dry mass of propeller, in kg

M_e = M (A + 2)

N = number of propeller blades

Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of service speed, calculations using a more accurate method will be required.

3.4 Measurements

3.4.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

3.5 Restricted speed ranges

3.5.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.5.2 Limits of a speed restriction, where required, may be determined by calculation or on the basis of measurement.

3.5.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the machinery operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

3.6 Vibration monitoring

3.6.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 4* Lateral vibration

4.1 General

4.1.1 Long unsupported lengths of main propulsion shafting are to be avoided by the fitting of steady bearings at suitable positions. In determining these positions, the Shipbuilder is to ensure that no harmful lateral vibrations are present throughout the speed range, so far as is practicable.

4.2 Particulars to be submitted

4.2.1 Calculations of the lateral vibration characteristics of shafting systems incorporating cardan shafts are to be submitted to LR for approval, irrespective of the power output.

4.3 Calculations

4.3.1 The calculations in *Pt 5, Ch 6, 4.2 Particulars to be submitted 4.2.1*, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies giving rise to all critical speeds which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

4.3.2 Requirements for calculations may be waived upon request, provided evidence of satisfactory service experience of similar dynamic installations is submitted.

4.3.3 For cardan shafts fitted in the high speed part of thruster drives, lateral vibration calculations are only required for the high speed part of the installation i.e. it is not mandatory to carry out lateral vibration calculations for the complete dynamic system.

4.4 Measurements

4.4.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of ±20 per cent of the M.C.R. speed, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.4.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 5* Shaft alignment

5.1 General

5.1.1 Shaft alignment calculations are to be carried out for main propulsion shafting rotating at propeller speed, including the final reduction gear wheel on geared installations. The Builder is to make available shaft alignment procedures detailing the proposed alignment method and checks for these arrangements.

5.2 Particulars to be submitted for approval – shaft alignment calculations

5.2.1 Shaft alignment calculations are to be submitted to LR for approval for the following shafting systems:

(a) all geared installations, where the screwshaft has a diameter of 300 mm or greater in way of the aftermost bearing, except for multiple input/single output geared installations, in which case all such installations will be submitted for approval;
(b) Where prime movers in a direct drive installation or shaft line bearings are installed on resilient mountings.

5.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the ship's operating draughts;
(c) effect of predicted hull deformations over the range of the ship’s operating draughts, where known;
(d) effect of filling the aft peak ballast tank upon the bearing loads, where known;
(e) gear forces, where appropriate, due to prime-mover engagement on multiple-input/single-output installations. For multiple input systems, consideration is to be given to each possible combination of inputs;
(f) propeller offset thrust effects
(g) maximum allowed bearing weardown, for water or grease-lubricated sterntube bearings, and its effect on the bearing loads.

5.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;

(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) expected hull deformation effects and their origin, *viz*. whether finite element calculations or measured results from sister or similar ships have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(i) manufacturer's allowable bearing loads.

5.3 Shaft alignment procedures

5.3.1 A shaft alignment procedure is to be made available for review and for the information of the attending Surveyors for all main propulsion installations detailing, as a minimum:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) proposed bearing load measurement technique and its estimated accuracy;
(i) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(j) proposed shaft alignment acceptance criteria, including the tolerances; and
(k) flexible coupling alignment criteria.

5.4 Design and installation criteria

5.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of ship loading and machinery operation, bearing load distribution satisfying the requirements of *Pt 5, Ch 6, 5.4 Design and installation criteria 5.4.2*.

5.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimize the effects of hull deflections under any of the ship's operating conditions with the aim of optimising the bearing load distribution.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.
(c) Sterntube bearing loads are to satisfy the requirements of *Pt 5, Ch 4, 3.12 Sternbushes and sterntube arrangement*.
(d) Evidence is to be provided to LR demonstrating that bearings of synthetic material have been verified as being within the tolerance stated by the bearing manufacturer for diameter, ovality, and straightness after installation.
(e) Bearings of synthetic material are to be verified as being within tolerance for ovalilty and straightness, circumferentially and longitudinally, after installation.
(f) The sterntube forward bearing static load is to be sufficient to prevent unloading in all static and dynamic operating conditions, including the transient conditions experienced during manoeuvring turns.
(g) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(h) Equipment manufacturer's bearing loads are to be within the manufacturer's specified limits, i.e. prime movers, gearing.
(i) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions.
(j) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

5.5 Measurements

5.5.1 The system bearing load measurements are to be carried out to verify that the design loads have been achieved. In general the measurements will be carried out by the jack-up measurement technique using calibrated equipment.

5.5.2 For the first vessel of a new design an agreed programme of static shaft alignment measurements is to be carried out in order to verify that the shafting has been installed in accordance with the design assumptions and to verify the design assumptions in respect of the hull deflections and the effects of machinery temperature changes. The programme is to include static bearing load measurements in a number of selected conditions. Depending on the ship type and the operational loading conditions that are achievable prior to and during sea trials these should include, where practicable, combinations of light ballast cold, full ballast cold, full ballast hot and full draught hot with aft peak tank empty and full.

5.5.3 For vessels of an existing design or similar to an existing design where evidence of satisfactory service experience is submitted for consideration and for subsequent ships in a series a reduced set of measurements may be accepted. In such cases the minimum set of measurements is to be sufficient to verify that the shafting has been installed in accordance with the design assumptions and are to include at least one cold and one hot representative condition.

5.5.4 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the shaft alignment is to be verified by measurements during trials using an approved strain gauge technique.

5.6 Flexible couplings

5.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see Pt 5, Ch 6, 2 Torsional vibration*, *Pt 5, Ch 6, 3 Axial vibration* and *Pt 5, Ch 6, 4 Lateral vibration*.

Section 1
General service

1.1 General

1.1.1 Where the notation 'Ice' as specified in *Pt 1, Ch 2 Classification Regulations* is desired, the following requirements are to be complied with, so far as these are applicable.

1.2 Materials for shafting

1.2.1 All components of the main propulsion system are to be of steel or other approved material.

1.3 Materials for propellers

1.3.1 Propellers and propeller blades are to be of cast steel or copper alloys having specified minimum tensile strengths as stated in *Table 5.2.1 Materials for propellers* in Chapter 5.

1.4 Main engine shafting and propellers

1.4.1 The diameter of the screwshaft as required by *Pt 5, Ch 4, 3.5 Hollow shafts* is to be increased by five per cent.

1.4.2 The thickness of the propeller blades at the root and at 60 per cent radius as required by *Pt 5, Ch 5, 3.1 Minimum blade thickness* are to be increased by eight per cent.

1.4.3 The tip thickness, *t*, of the blade at 95 per cent radius is to be not less than that obtained by the following formula:

$$t = 0,14(T + 57)\sqrt[3]{\frac{430}{\sigma_u}} \text{ mm}$$

where

T = blade root thickness required, in mm

σ_u = specified minimum tensile strength of material, in N/mm^2

1.4.4 For keyless propellers the mean torque Q as defined in *Pt 5, Ch 5, 3.2 Keyless propellers* is to be increased by 15 per cent.

1.5 CROSS REFERENCES

1.5.1 For hull requirements, *see Pt 3 Ship Structures (General)*.

Section 1
General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, for the following uses:

(a) Production or storage of steam.
(b) Heating of pressurised hot water above 120°C.
(c) Heating of pressurised thermal liquid.

Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of *Ch 5 Steel Forgings* of the *Rules for the Manufacture, Testing and Certification of Materials*.

1.1.2 The scantlings of coil type heaters with pumped circulation, which are fired or heated by exhaust gas are to comply with the appropriate requirements of *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels* the Rules and Regulations for the Classification of Ships (hereinafter referred to as the Rules for Ships).

1.1.3 Where exhaust gas emissions abatement equipment is fitted to steam raising plant, it is to meet the requirements of *Pt 5, Ch 24 Emissions Abatement Plant for Combustion Machinery* of the Rules for Ships.

1.2 Plans

1.2.1 Plans of boilers, having working pressures exceeding 3,4 bar and having heating surfaces greater than 4,65 m^2 are to be submitted in triplicate for approval before construction is commenced.

1.2.2 These plans should give full constructional features of fusion welded pressure vessels and dimensional details of the weld preparation for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials.

1.2.3 Boiler Manufacturers are referred to in *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels* of the Rules for Ships,, which contain detailed requirements for the materials, the manufacture and testing of boilers.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not for steam raising plant. The equations of this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of *Ch 5 Steel Forgings* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). For design requirements of pressure vessels intended for the carriage of liquefied gases, *see Pt 5, Ch 13 Piping Systems for Ships Intended for the Carriage of Liquids in Bulk*.

1.1.2 Where the required design criteria for pressure vessels are not indicated within this Chapter, the relevant Sections of *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels* of the Rules and Regulations for the Classification of Ships (hereinafter referred to as the Rules for Ships) are applicable.

1.1.3 Seamless pressure vessels are to be manufactured in accordance with the requirements of the Rules for Materials where applicable.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in *Pt 5, Ch 9, 2 Cylindrical shells and drums subject to internal pressure* inclusive, unless otherwise stated, are defined as follows, and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole or opening, in mm

p = design pressure, in MPa, *see Pt 5, Ch 9, 1.3 Design pressure*

r_i = inside knuckle radius, in mm

r_o = outside knuckle radius, in mm

t = minimum thickness, in mm

D_i = inside diameter, in mm

D_o = outside diameter, in mm

J = joint factor applicable to welded seams, *see Pt 5, Ch 9, 1.9 Joint factors*

R_i = inside radius, in mm

R_o = outside radius, in mm

T = design temperature, in °C

σ = allowable stress, in N/mm^2, *see Pt 5, Ch 9, 1.8 Allowable stress*.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure, and is to be not less than the highest set pressure of any relief valve.

1.3.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The design temperature, T, for calculation purposes is to be not less than 50°C.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.5.2 For Rule purposes, pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 1,72 MPa; or
(b) where the metal temperature exceeds 150°C; or
(c) where the design pressure, in MPa, multiplied by the actual thickness of the shell, in mm, exceeds 15,7; or
(d) where the shell thickness does not exceed 38 mm.

1.5.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Class 1, 2/1 or 2/2.

1.5.4 Pressure vessels which are constructed in accordance with Class 2/1, 2/2 or 3 standards (as indicated in *Pt 5, Ch 9, 1.5 Classification of fusion welded pressure vessels 1.5.2* and *Pt 5, Ch 9, 1.5 Classification of fusion welded pressure vessels 1.5.3*) will, if manufactured in accordance with the requirements of a superior Class, be approved with the scantlings appropriate to that Class.

1.5.5 Pressure vessels which only have circumferential fusion welded seams, will be considered as seamless with no Class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent Class as determined by *Pt 5, Ch 9, 1.5 Classification of fusion welded pressure vessels 1.5.1*, *Pt 5, Ch 9, 1.5 Classification of fusion welded pressure vessels 1.5.2* and *Pt 5, Ch 9, 1.5 Classification of fusion welded pressure vessels 1.5.3*.

1.5.6 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc. it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior Class.

1.5.7 Details of heat treatment, non-destructive examination and routine tests (where required) are given in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

1.5.8 Hydraulic testing is required for all Classes of pressure vessels.

1.5.9 For a full definition of Classes of pressure vessels relating to boilers and associated pressure vessels, *see Pt 5, Ch 10, 1 General requirements* of the Rules for Ships.

1.6 Plans

1.6.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and

$pV > 60$

$p > 0{,}1$

$V > 100$

V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases for fire-fighting or flammable liquids, and

$p > 0{,}7$

$V > 100$

V = volume (litres)

p is as defined in *Pt 5, Ch 9, 1.2 Definition of symbols 1.2.1*.

1.6.2 Plans of full constructional features of the vessel and dimensional details of the weld preparations for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.7 Materials

1.7.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable national or international specification. The manufacturer's certificate will be accepted in lieu of Lloyd's Register's (hereinafter referred to as LR's) material certificate for such materials.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the general limits of 340 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2, and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by LR.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1{,}5} \qquad \sigma = \frac{R_{20}}{2{,}7}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature T for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used

R_{20} = specified minimum tensile strength at room temperature

T = metal temperature, *see Pt 5, Ch 9, 1.4 Metal temperature*.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in *Pt 5, Ch 9, 1.8 Allowable stress 1.8.2* using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the Rules for Materials are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in *Pt 5, Ch 9, 1.8 Allowable stress 1.8.3*. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in *Pt 5, Ch 9, 2 Cylindrical shells and drums subject to internal pressure* and *Pt 5, Ch 9, 3 Dished ends subject to internal pressure*. Fusion welded pressure parts are to be made in accordance with *Pt 5, Ch 14 Requirements for Fusion Welding of Pressure Vessels and Piping*.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels are also to be butt welds. Circumferential joints for Class 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Class 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching flat ends, *see Figure 9.6.1 Typical methods of attachment of un-stayed circular flat end plates*.

For typical acceptable methods of attaching dished ends, *see Figure 9.7.1 Typical attachments of dished ends to cylindrical shells*.

1.9.3 Where a pressure vessel is to be made of alloy steel, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.10 Adverse working conditions

1.10.1 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulæ. In this connection, where necessary, account should also be taken of any excess loading resulting from:

(a) Impact loads, including rapidly fluctuating pressures.
(b) Weight of the vessel and normal contents under operating and test conditions.
(c) Superimposed loads, such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping.
(d) Reactions of supporting lugs, rings, saddles or other types of supports, or
(e) The effect of temperature gradients on maximum stress.

1.11 Pressure parts of irregular shape

1.11.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulae in *Pt 5, Ch 9, 2 Cylindrical shells and drums subject to internal pressure*, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

■ *Section 2*
Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 The minimum thickness, *t*, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{pR_{\text{i}}}{10\,\sigma\,J - 0,5p} + 0,75 \text{ mm}$$

where

t, *p*, R_{i} and σ are as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*

J = the joint factor of the longitudinal joints (expressed as a fraction), *see Pt 5, Ch 9, 1.9 Joint factors*. In the case of seamless shells clear of openings *J* = 1,0.

2.1.2 The formula in *Pt 5, Ch 9, 2.1 Minimum thickness 2.1.1* is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_{o} is not greater than 1,5 R_{i}.

2.1.3 Irrespective of the thickness determined by the formula in *Pt 5, Ch 9, 2.1 Minimum thickness 2.1.1*, t is to be not less than 3 + $\frac{D_{\text{i}}}{1500}$ mm, where D_{i} is as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*.

2.1.4 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

2.2 Unreinforced openings

2.2.1 The maximum diameter, *d*, of any unreinforced isolated opening is to be determined by the following formula:

$$d = 8,08\,[D_{\text{o}}\,t\,(1 - K)]^{1/3} \text{ mm}$$

The value of K to be used is calculated from the following formula:

$$K = \frac{pD_o}{18,2\,\sigma\,t}$$ but is not to be taken as greater than 0,99

= where

p, D_{o} and σ are as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*

t = actual thickness of shell, in mm.

2.2.2 For elliptical or oval holes, *d* for the purposes of *Pt 5, Ch 9, 2.2 Unreinforced openings 2.2.1*, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.2.3 No unreinforced opening is to exceed 200 mm in diameter.

2.2.4 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$d + 1,1\sqrt{Dt}$ with a minimum 5*d*

where

d = diameter of openings in shell (mean diameter if dissimilarly sized holes involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

2.3 Reinforced openings

2.3.1 Openings larger than those permitted by*Pt 5, Ch 9, 2.2 Unreinforced openings* are to be compensated in accordance with *Figure 9.2.1 Compensation for welded standpipes or branches in cylindrical shells* (a) or (b). The following symbols are used in *Figure 9.2.1 Compensation for welded standpipes or branches in cylindrical shells* (a) and (b):

d_o = diameter of hole in shell, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_d = thickness calculated in accordance with *Pt 5, Ch 9, 5.1 Minimum thickness 5.1.1* without corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

C = $\sqrt{d_o t_b}$ in mm

D = $\sqrt{D_i t_a}$ and is not to exceed 0,5d_o, in mm

D_i = internal diameter of cylindrical shell, in mm

L = width of added reinforcement not exceeding D, in mm

σ = shell plate allowable stress, in N/mm^2

σ_p = standpipe allowable stress, in N/mm^2

σ_r = added reinforcement allowable stress, in N/mm^2

σ_w = weld metal allowable stress, in N/mm^2

Note σ_p, σ_r and σ_w are not to be taken as greater than σ.

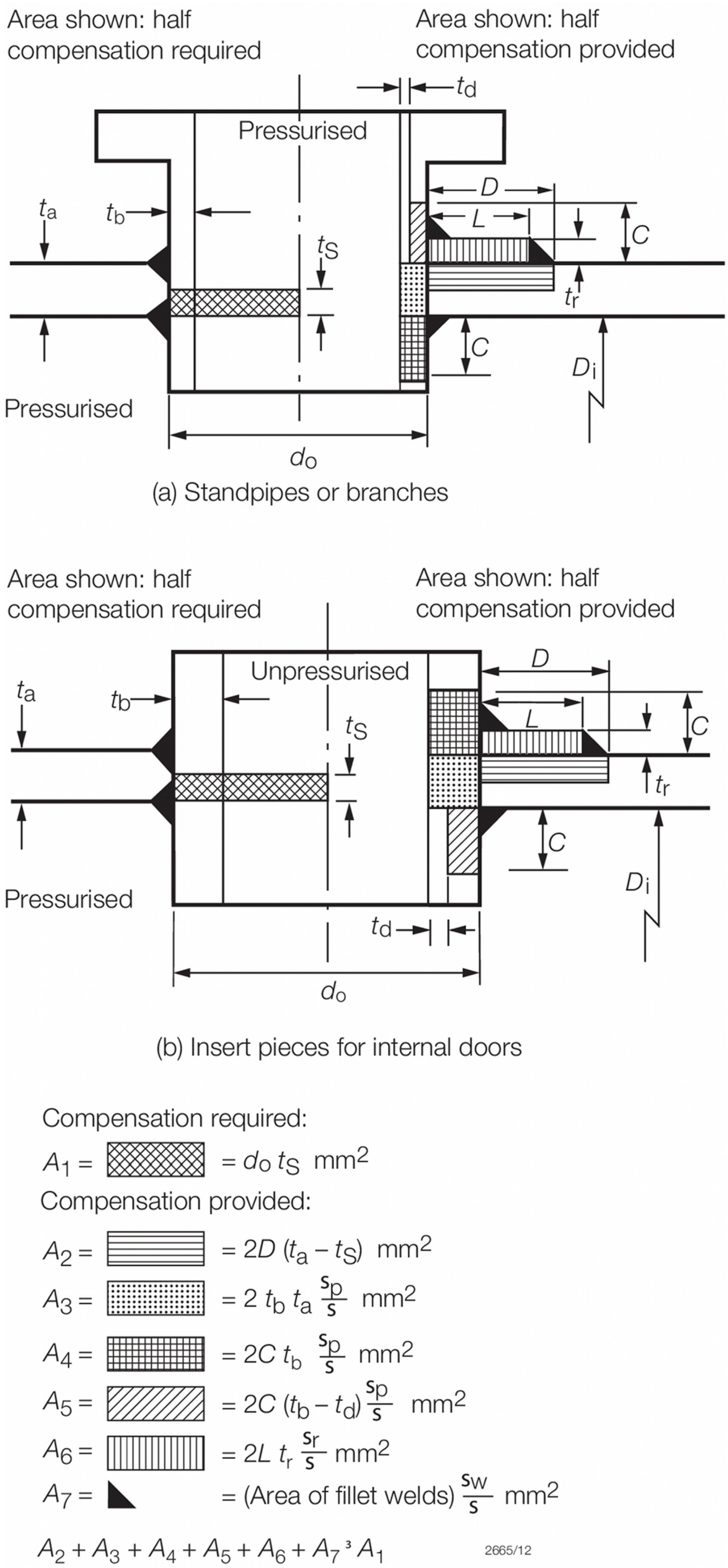


Figure 9.2.1 Compensation for welded standpipes or branches in cylindrical shells

2.3.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in *Pt 5, Ch 9, 2.3 Reinforced openings 2.3.1*.

2.3.3 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

2.3.4 Compensation is to be distributed equally on either side of the centreline of the opening.

■ *Section 3* Dished ends subject to internal pressure

3.1 Minimum thickness

3.1.1 The thickness, *t*, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{pD_oK}{20\,\sigma\,J} + 0,75 \text{ mm}$$

where

t, p, D_o, σ and J are as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*

K = a shape factor, *see Pt 5, Ch 9, 3.2 Shape factors for dished ends* and *Figure 9.3.1 Shape factor*.

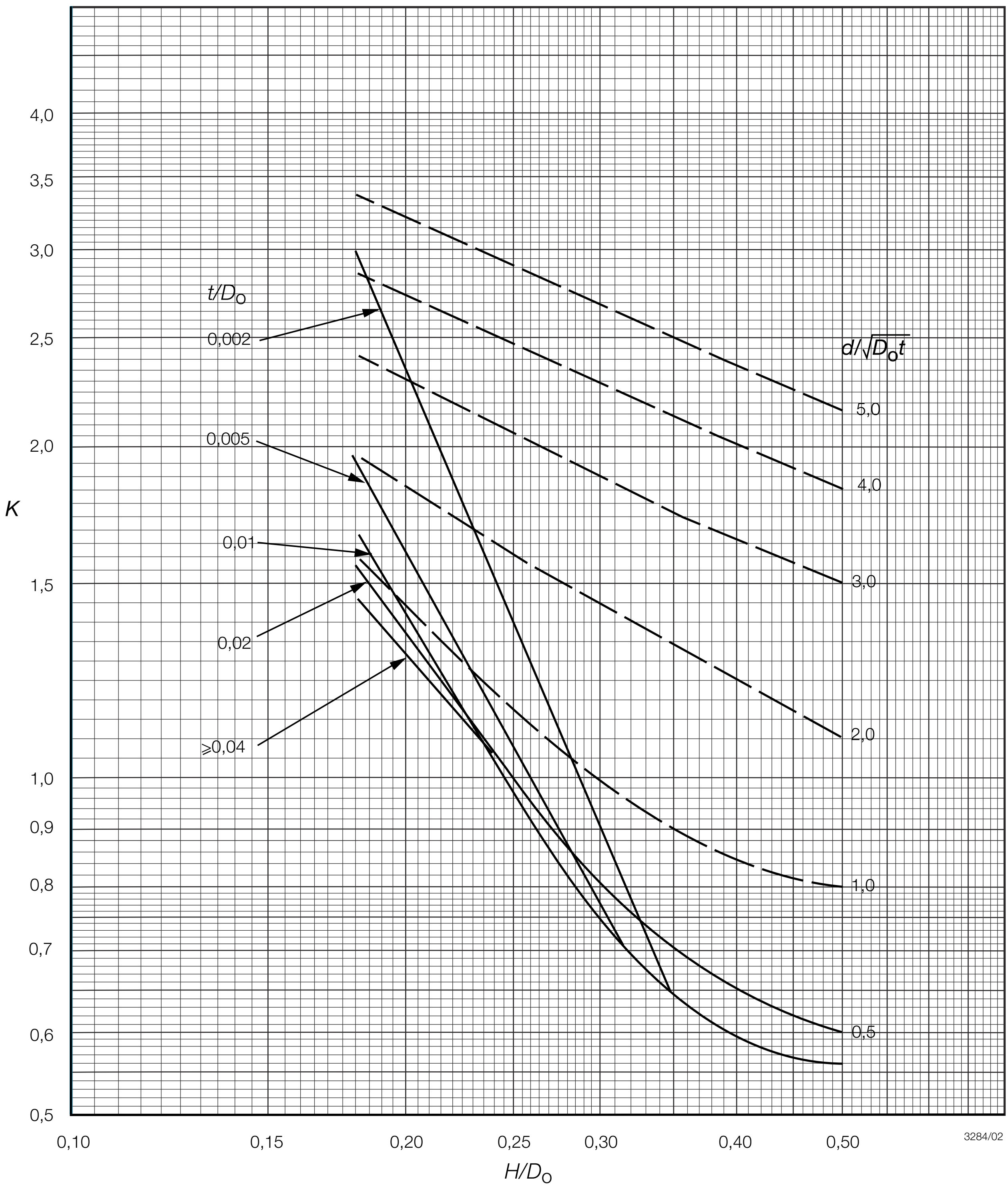


Figure 9.3.1 Shape factor

3.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_{o}$

where

D_o = the external diameter of the parallel portion of the end, in mm

3.1.3 For torispherical ends:

the internal radius, $R_i \leq D_o$

the internal knuckle radius, $r_i \geq 0{,}1D_o$

the internal knuckle radius, $r_i \geq 3t$

the external height, $H \geq 0{,}18D_o$, and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}$$

3.1.4 In addition to the formula in *Pt 5, Ch 9, 3.1 Minimum thickness 3.1.1* the thickness, *t*, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{pR_i}{20\sigma J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, *p*, R_i, σ and $_J$ are as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*.

3.1.5 The thickness required by *Pt 5, Ch 9, 3.1 Minimum thickness 3.1.1* for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_i t}$ mm , before reducing to the crown thickness permitted by *Pt 5, Ch 9, 3.1 Minimum thickness 3.1.4*

where

t = the required thickness from *Pt 5, Ch 9, 3.1 Minimum thickness 3.1.1*.

3.1.6 In all cases, *H* is to be measured from the commencement of curvature, *see Figure 9.3.2 Typical dished ends*.

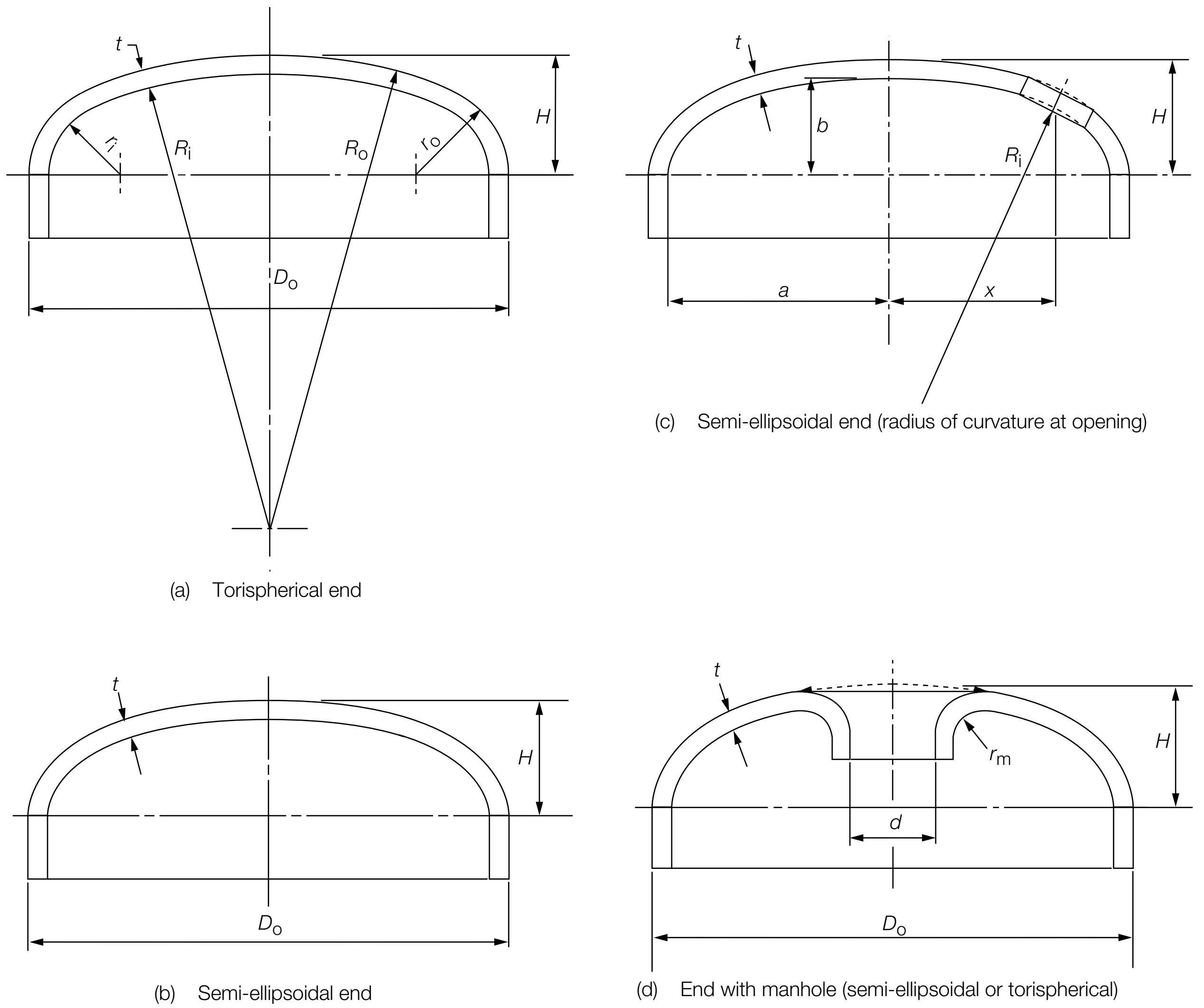


Figure 9.3.2 Typical dished ends

3.1.7 The minimum thickness of the head, *t*, is not to be less than $3 + \frac{D_i}{1500}$ mm where D_i is as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*.

3.1.8 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.9 For ends which are butt welded to the drum shell, *see Pt 5, Ch 9, 1.9 Joint factors*, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by *Pt 5, Ch 9, 2.1 Minimum thickness*.

3.2 Shape factors for dished ends

3.2.1 The shape factor, *K*, to be used in *Pt 5, Ch 9, 3.1 Minimum thickness 3.1.1*, is to be obtained from the curves in *Figure 9.3.1 Shape factor* and depends on the ratio of height to diameter $\frac{H}{D_o}$.

3.2.2 The lowest curve in the series provides the factor, *K*, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, *K* depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of *K*.

3.3 Dished ends with unreinforced openings

3.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

3.3.2 The upper curves in *Figure 9.3.1 Shape factor* provide values of *K* to be used in *Pt 5, Ch 9, 3.1 Minimum thickness 3.1.1*, for ends with unreinforced openings. The selection of the correct curve depends on the value $\frac{d}{\sqrt{D_o t}}$ and a trial calculation is necessary to select the correct curve,

where

d = the diameter of the largest opening in the end plate (in the case of an elliptical opening, the larger axis of the ellipse), in mm

t = minimum thickness, after dishing, in mm

D_o = outside diameter of dished end, in mm.

3.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} = \leq 0{,}10$$

$$\frac{d}{D_o} = \leq 0{,}70$$

3.3.4 From *Figure 9.3.1 Shape factor* for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for *K*. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

3.4 Flanged openings in dished ends

3.4.1 The requirements in *Pt 5, Ch 9, 3.3 Dished ends with unreinforced openings* apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

3.4.2 Where openings are flanged, the radius, r_m, of the flanging is to be not less than 25 mm, *see Figure 9.3.2 Typical dished ends*(d). The thickness of the flanged portion may be less than the calculated thickness.

3.5 Location of unreinforced and flanged openings in dished ends

3.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in*Figure 9.3.3 Opening in dished ends*.

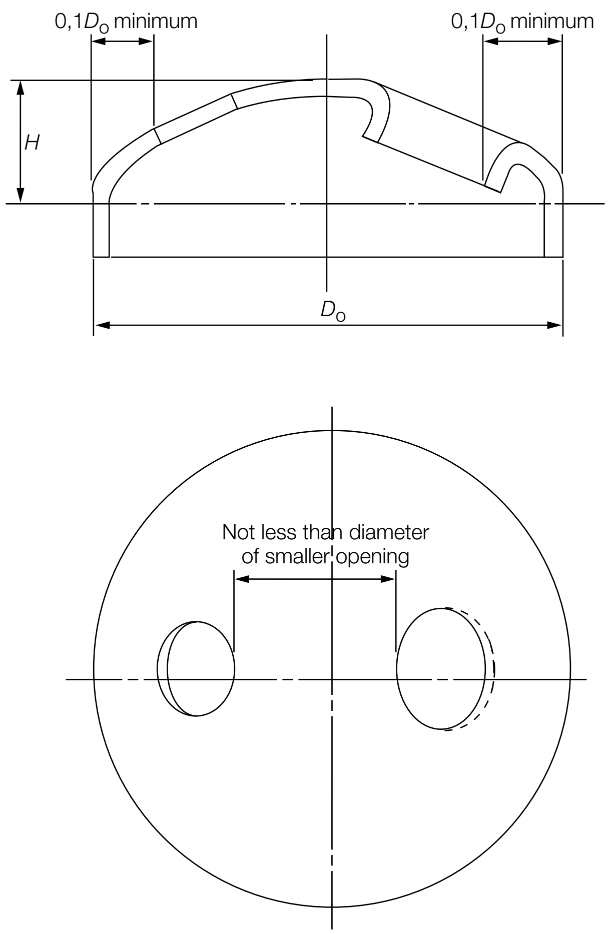


Figure 9.3.3 Opening in dished ends

3.6 Dished ends with reinforced openings

3.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by *Pt 5, Ch 9, 3.3 Dished ends with unreinforced openings*, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see Figure 9.3.4 Limits of reinforcement*. Forged reinforcements may be used.

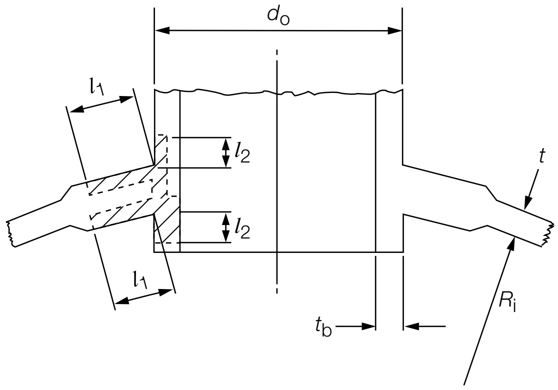


Figure 9.3.4 Limits of reinforcement

3.6.2 Reinforcing material within the following limits may be taken as effective reinforcement:

(a) The effective width l_1 of reinforcement is not to exceed $\sqrt{2R_i t}$ or $0{,}5d_o$, whichever is the lesser.

(b) The effective length l_2 of a reinforcing ring is not to exceed $\sqrt{d_o t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

R_i = the internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{\sqrt{\left(a^4 - x^2\left(a^2 - b^2\right)\right)^3}}{a^4 b}$$

where

a, b and x = are shown in *Figure 9.3.2 Typical dished ends*

d_o = external diameter of ring or standpipe, in mm

t_b = actual thickness of ring or standpipe, in mm

l_1 and l_2 are as shown in *Figure 9.3.4 Limits of reinforcement*.

3.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from *Figure 9.3.1 Shape factor* using the value obtained from:

$$\frac{d_0 - \frac{A}{t}}{\sqrt{D_o t}} \text{ and } \frac{d}{\sqrt{D_o t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on *Figure 9.3.4 Limits of reinforcement*.

As in *Pt 5, Ch 9, 3.3 Dished ends with unreinforced openings*, a trial calculation is necessary in order to select the correct curve.

3.6.4 The area shown in *Figure 9.3.4 Limits of reinforcement* is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1
- plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to the distance l_2
- plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance l_2, and deduct the sectional area which the ring of standpipe would have if its thickness were as calculated in accordance with *Pt 5, Ch 9, 6.1 Minimum thickness*.

3.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, *A*, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

3.7 Torispherical dished ends with reinforced openings

3.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of *Pt 5, Ch 9, 3.6 Dished ends with reinforced openings* are to be applied.

■ *Section 4* Dished ends for Class 3 pressure vessels

4.1 Minimum thickness

4.1.1 As an alternative to the formula in *Pt 5, Ch 9, 3.1 Minimum thickness 3.1.1* for Class 3 vessels only, the minimum thickness, *t*, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:

$$t = \frac{pR_i}{CS}$$

where

t, p and R_i are as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*

C = 2,57 for ends concave to pressure

= 1,65 for ends convex to pressure

S = specified minimum tensile strength of plate, in N/mm^2, which should be not less than 410 N/mm^2.

4.1.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

4.1.3 The inside knuckle radius, r_i, of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

4.1.4 Ends convex to pressure are not to be used for vessels exceeding 610 mm internal diameter.

4.1.5 Where the end is provided with a flanged manhole, the thickness of the end, in mm, determined by *Pt 5, Ch 9, 4.1 Minimum thickness 4.1.1*, is to be increased by 3 mm, and the total depth, *H*, of the manhole flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t_1 W}$$

where

t_1 = required thickness of the plate, in mm

H = depth of flange, in mm

W = minor axis of the manhole, in mm.

Section 5
Standpipes and branches

5.1 Minimum thickness

5.1.1 The minimum wall thickness, t, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibration:

$$t = \frac{pD_o}{20\sigma + p} + 0,75 \text{ mm}$$

$$t = 0,015D_o + 3,2 \text{ mm}$$

where

t, p, D_o and σ are as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*.

If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3,5\sqrt{D_o t} \text{ mm}$$

5.1.2 In no case need the wall thickness exceed the minimum shell thickness as required by *Pt 5, Ch 9, 2.1 Minimum thickness* or *Pt 5, Ch 9, 3.1 Minimum thickness*, as applicable.

Section 6
Unstayed circular flat end plates

6.1 Minimum thickness

6.1.1 Ends attached by welding are to be designed such that the minimum thickness of flat plates is to be determined by the following formula:

$$t = d_i\sqrt{\frac{pC}{\sigma}} + 0,75 \text{ mm}$$

where

p and σ are as defined in *Pt 5, Ch 9, 1.2 Definition of symbols*

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular shell, in mm

C = a constant depending on method of end attachment, *see Figure 9.6.1 Typical methods of attachment of un-stayed circular flat end plates*.

(a) For end plates welded as shown in *Figure 9.6.1 Typical methods of attachment of un-stayed circular flat end plates*(a):

C = 0,019 for circular shells.

(b) For end plates welded as shown in *Figure 9.6.1 Typical methods of attachment of un-stayed circular flat end plates*(b) and (c)

C = 0,028 circular shells.

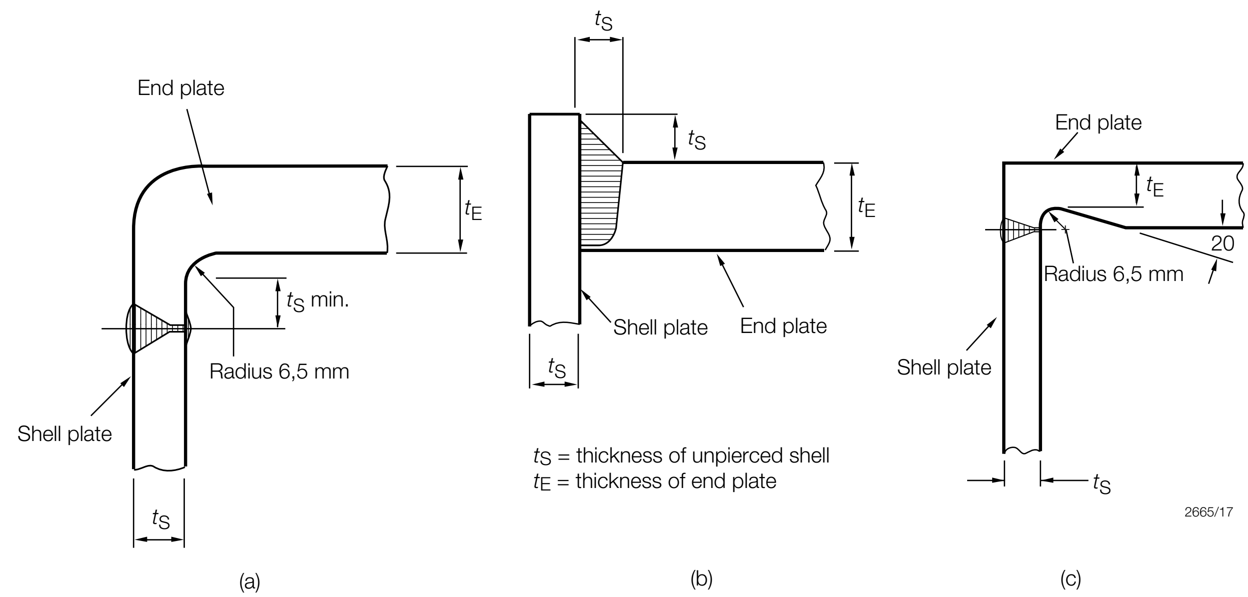


Figure 9.6.1 Typical methods of attachment of un-stayed circular flat end plates

6.1.2 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognized pipe flange standards.

6.1.3 Openings in flat plates are to be compensated in accordance with *Figure 9.6.1 Typical methods of attachment of un-stayed circular flat end plates*(a) or (b), with the value of A1, the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2,4} t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with*Pt 5, Ch 9, 6.1 Minimum thickness 6.1.1*, as applicable, without corrosion allowance

Limit D = 0,5d_o.

■ *Section 7* Construction

7.1 Access arrangement

7.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

7.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

7.1.3 Doors for manholes and sightholes are to be formed from steel plate or other approved construction, and all jointing surfaces are to be machined.

7.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the gasket seat is not to be less than 16 mm.

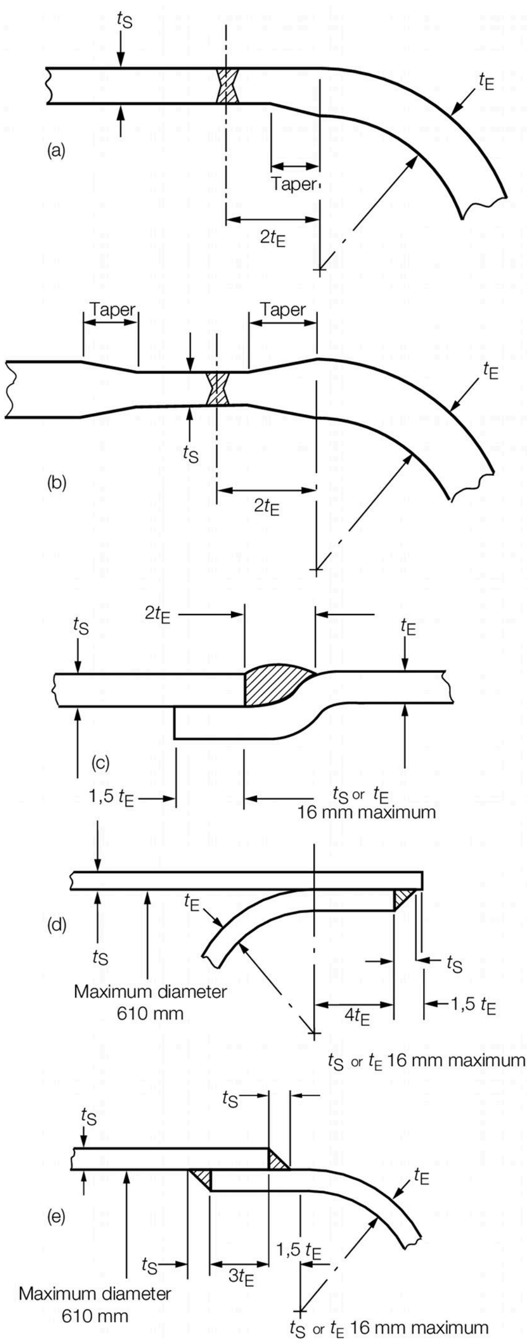
7.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

7.1.6 The crossbars or dogs for doors are to be of steel.

7.1.7 External circular flat cover plates are to be in accordance with a recognized standard.

7.2 Torispherical and semi-ellipsoidal ends

7.2.1 For typical acceptable types of attachment for dished ends to cylindrical shells, *see Figure 9.7.1 Typical attachments of dished ends to cylindrical shells*. Types (d) and (e) are to be made a tight fit in the cylindrical shell.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

Figure 9.7.1 Typical attachments of dished ends to cylindrical shells

7.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at

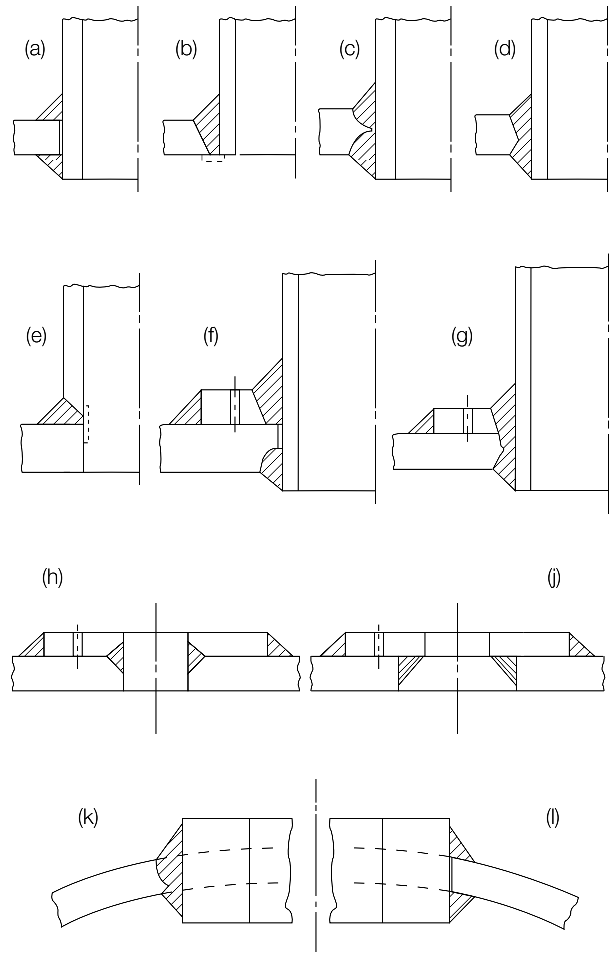
the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

7.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see Pt 5, Ch 9, 3.1 Minimum thickness*.

7.3 Welded attachments to pressure vessels

7.3.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimize load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service, *see Pt 5, Ch 14 Requirements for Fusion Welding of Pressure Vessels and Piping*.

7.3.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see Figure 9.7.2 Typical acceptable methods of attaching branches and pads*. Alternative methods of attachment may be accepted provided details are submitted for consideration.



Types (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e)

Figure 9.7.2 Typical acceptable methods of attaching branches and pads

7.3.3 Where fillet welds are used to attach standpipes or set-in pads, there are to be equal sized welds both inside and outside the vessel, *see Figure 9.7.2 Typical acceptable methods of attaching branches and pads*(a) and (l). The leg length of each of the fillet welds is to be not less than 1,4 times the actual thickness of the thinner of the parts being joined.

7.4 Welded-on flanges, butt welded joints and fabricated branch pieces

7.4.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

7.4.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

7.4.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognized standards will be accepted.

7.4.4 Typical examples of welded-on flange connections are shown in *Figure 9.7.3 Typical examples of welded flange connections*(a) to (f). Types (c) and (e), however, are not to be used for pipes having a bore of less than 75 mm.

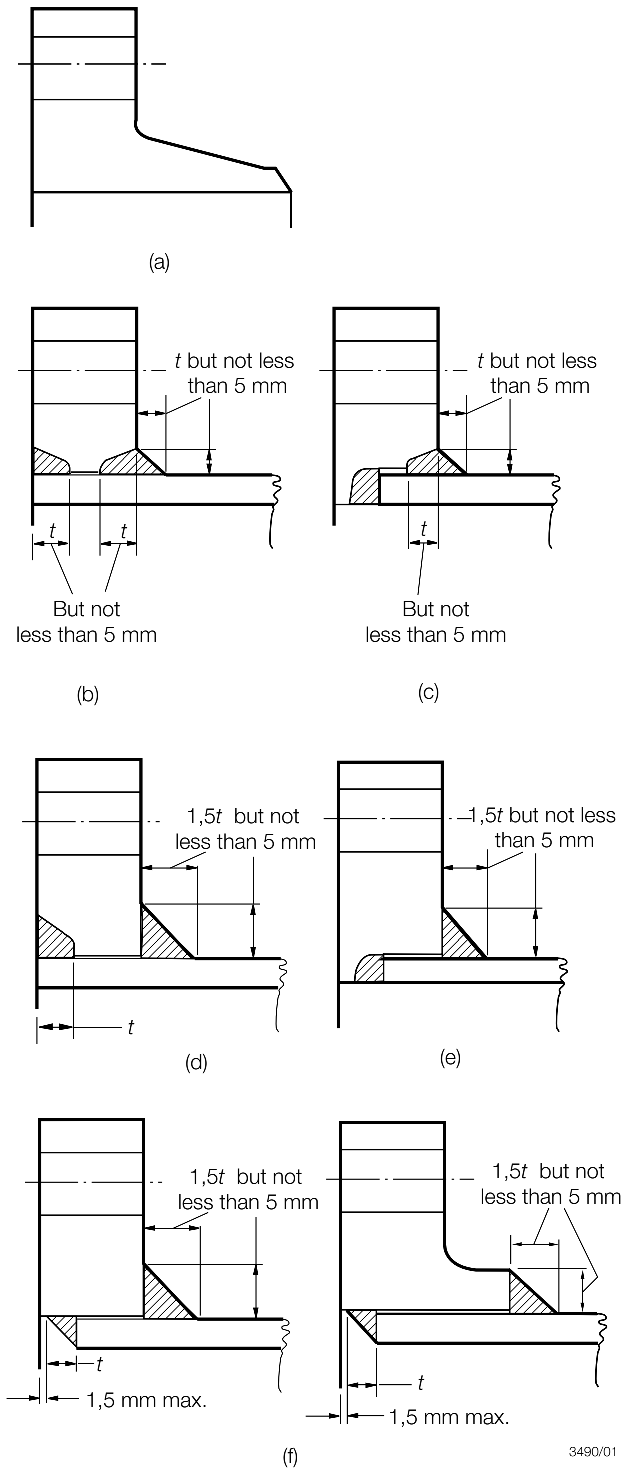


Figure 9.7.3 Typical examples of welded flange connections

7.4.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the diametrically opposite clearances is not to exceed 5 mm.

7.4.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.

7.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of *Pt 5, Ch 14 Requirements for Fusion Welding of Pressure Vessels and Piping*.

■ *Section 8* Mountings and fittings

8.1 General

8.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

8.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

8.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

8.2 Receivers containing pressurized gases

8.2.1 Each receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

8.2.2 Each receiver is to be provided with a relief valve.

8.2.3 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also Pt 5, Ch 9, 8.2 Receivers containing pressurized gases 8.2.4* and *Pt 5, Ch 9, 8.2 Receivers containing pressurized gases 8.2.5*.

8.2.4 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing (an) air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

8.2.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Cross-reference*

For starting air pipe systems and safety fittings, *see Pt 5, Ch 2, 8.2 Exhaust systems*.

■ *Section 9* Hydraulic tests

9.1 General

9.1.1 Pressure vessels covered by this Chapter are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1,3 \frac{\sigma 50}{\sigma_T} \frac{t}{(t - 0,75)} p$$

but in no case is to exceed

$$p_T = 1,5\frac{t}{(t-0,75)}\,p$$

where

p = design pressure, in bar

p_T = test pressure, in bar

t = nominal thickness of shell as indicated on the plan, in mm

σ_T = allowable stress at design temperature, in N/mm^2

σ_{50} = allowable stress at 50°C, in N/mm^2.

9.2 Mountings

9.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 10* Plate heat exchangers

10.1 General

10.1.1 Plate heat exchangers are to be classed as follows. Class 2 where either of the following conditions apply:

(a) the maximum metal design temperature is 150°C, or greater, or
(b) design pressure is 17,2 bar, or greater. Class 3 in all other cases.

10.1.2 Where the design temperature is equal to, or lower than minus 10°C, a higher class is to apply.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems, including pipe fittings forming parts of such systems, including pipe fittings forming parts of such systems, where the temperature does not exceed 300°C.

1.1.2 For systems having temperatures greater than 300°C, the *Rules and Regulations for the Classification of Ships, July 2022* (hereinafter referred to as the Rules for Ships) will be applicable.

1.1.3 The materials used for pipes, valves and fittings are to be suitable for the medium and the service for which the piping is intended.

1.1.4 The piping systems for Type G tankers and gas fuelled ships are to comply with the relevant Sections of this Chapter where applicable and the additional requirements in *Pt 5, Ch 10, 9 Piping for Type G tankers and gas fuelled ships*, as well as the requirements in *Pt 5, Ch 13 Piping Systems for Ships Intended for the Carriage of Liquids in Bulk*.

1.2 Design symbols

1.2.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness

c = corrosion allowance, in mm

D = outside diameter of pipe, in mm, *see Pt 5, Ch 10, 1.2 Design symbols 1.2.2*

d = inside diameter of pipe, in mm, *see Pt 5, Ch 10, 1.2 Design symbols 1.2.3*

e = weld efficiency factor, *see Pt 5, Ch 10, 1.2 Design symbols 1.2.4*

p = design pressure, in MPa, *see Pt 5, Ch 10, 1.3 Design pressure*

p_t = hydraulic test pressure, in MPa

R = radius of curvature of a pipe bend at the centreline of the pipe, in mm

T = design temperature, in °C, *see Pt 5, Ch 10, 1.4 Design temperature*

t = minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance where applicable

t_b = the minimum thickness of a straight pipe, in mm, to be used for a pipe bend including bending allowance corrosion allowance and negative tolerance, where applicable.

σ = maximum permissible design stress, in N/mm^2.

1.2.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

1.2.3 The inside diameter, d, is not to be confused with nominal pipe size, which is an accepted designation associated with outside diameters of standard rolling sizes.

1.2.4 The weld efficiency factor, e, is to be taken as 1 for seamless and electric resistance and induction welded steel pipes. Where other methods of pipe manufacture are proposed, the value of e will be specially considered.

1.3 Design pressure

1.3.1 The design pressure, p, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve.

1.3.2 In boiler installations, the design pressure for steam piping is to be taken as the design pressure of the boiler, i.e. not less than the highest set pressure of any safety valve on the boiler.

1.3.3 The design pressure of feed piping and other piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

1.3.4 For design pressure of steering gear components and piping, *see Pt 5, Ch 15, 3.1 General 3.1.6*.

1.3.5 For design pressure of hydraulic system for liftable wheelhouse systems, *see Pt 5, Ch 18, 3.1 Hydraulic cylinder 3.1.5*.

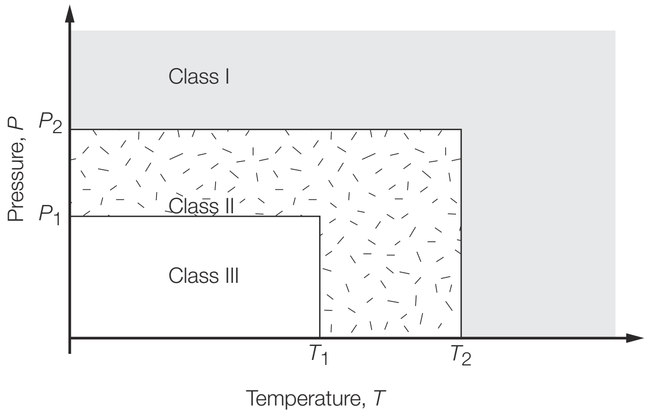
1.4 Design temperature

1.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

1.5 Classes of pipes

1.5.1 Pressure piping systems are divided into three classes for the purpose of assigning appropriate testing requirements, type of joints to be adopted, heat treatment and weld procedure.

1.5.2 Dependent on the service for which they are intended, Class II and III pipes are not to be used for design pressure or temperature conditions in excess of those shown in *Table 10.1.1 Maximum pressure and temperature conditions for Class II and Class III piping systems*. Where either the maximum design pressure or temperature exceeds that applicable to Class II pipes, Class I pipes are to be used. To illustrate this, *see Figure 10.1.1 Classes of piping system*. *See also Pt 5, Ch 10, 1.1 Application 1.1.2* for temperatures exceeding 300°.



NOTE
T_1 and P_1 correspond to the maximum temperatures and pressures for a Class III piping system and T_2 and P_2 to those for a Class II piping system depending on the service.

Figure 10.1.1 Classes of piping system

Table 10.1.1 Maximum pressure and temperature conditions for Class II and Class III piping systems

Piping system	Class II		Class III	
	p	T	p	T
	MPa	°C	MPa	°C
Steam	1,6	300	0,7	170
Thermal oil	1,6	300	0,7	150
Flammable liquids (*see* Note 1)	1,6	150	0,7	60
Other media	4	300	1,6	200
Cargo oil	4	300	1,6	200
Note 1. Flammable liquids include: fuel oil, lubricating oil and flammable hydraulic oil. Note 2. For Class limitations of grey cast iron, *see also Pt 5, Ch 10, 4.2 Grey cast iron*.				

1.5.3 In addition to the pressure piping systems in *Table 10.1.1 Maximum pressure and temperature conditions for Class II and Class III piping systems*, Class III pipes may be used for open ended piping, e.g. overflows, vents, boiler waste steam pipes, open ended drains, etc.

1.6 Materials

1.6.1 Materials for ferrous castings and forgings of Class I and Class II piping systems are to be produced at works approved by Lloyd's Register (hereinafter referred to as 'LR') unless otherwise specifically mentioned in the Rules. They are in general, to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* (hereinafter referred to as the Rules for Materials).

1.6.2 The manufacturer's test certificate for materials for pipes, valves and fittings of Class I and Class II piping systems will be accepted in lieu of LR's materials certificate where the maximum nominal pipe diameter is less than 50 mm or the product of working pressure in bar times nominal diameter in mm is less than 2500. *See Ch 1, 3.1 General 3.1.3.(c)* of the Rules for Materials.

1.6.3 For copper alloys having a working temperature < 200°C, the manufacturer's test certificate for materials for pipes, valves and fittings of Class I and Class II piping systems will be accepted in lieu of LR's materials certificate where the maximum nominal pipe diameter is less than 50 mm or the product of working pressure in bar times nominal diameter in mm is less than 1500. *See Ch 1, 3.1 General 3.1.3.(c)* of the Rules for Materials.

1.6.4 The manufacturer's certificate for materials for ship-side valves and fittings and valves on the collision bulkhead equal to or less than 500 mm nominal diameter will be accepted in lieu of LR's materials certificate where the valves and fittings are in accordance with a recognised National Standard applicable to the intended application and are manufactured and tested in accordance with the appropriate requirements of *Ch 1, 3.1 General 3.1.3.(c)* of the Rules for Materials.

■ *Section 2* Carbon and low alloy steels

2.1 Carbon and low alloy steel pipes, valves and fittings

2.1.1 Materials for Class I and Class II piping systems, also for shipside valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the appropriate requirements of the Rules for Materials, *see also Pt 5, Ch 10, 1.6 Materials*.

2.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national specifications. Pipes having forge butt welded longitudinal seams are not to be used for fuel oil systems, for heating coils in oil tanks, or for pressures exceeding 4,0 bar. The manufacturer’s certificate will be acceptable and is to be provided for each consignment of material. *See Ch 1, 3.1 General 3.1.3.(c)* of the Rules for Materials.

2.2 Wrought steel pipes and bends

2.2.1 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6} \qquad \sigma = \frac{R_{20}}{2,7}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature. In the case of austenitic stainless steels, the 1,0 per cent proof stress at design temperature is to be used.

R_{20} = specified minimum tensile strength at ambient temperature.

Values of the maximum permissible design stress, σ, may be obtained from the properties of the steels specified in Chapter 6 of the Rules for Materials are shown in *Table 10.2.1 Mechanical properties of finished chain cable and fittings* for carbon and carbon-manganese steels. For intermediate values of specified minimum tensile strengths and temperatures, values of the permissible design stress may be obtained by interpolation.

2.2.2 Where it is proposed to use alloy steels other than those detailed in *Ch 6 Steel Pipes and Tubes* of the Rules for Materials, particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

2.2.3 The minimum thickness, *t*, of straight steel pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\,\sigma\,e + p} + c\right)\frac{100}{100 - a}\ \text{mm}$$

where

p, *D*, *e* and a are defined in *Pt 5, Ch 10, 1.2 Design symbols 1.2.1*

σ is defined in *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.1* and obtained from *Table 10.2.1 Carbon and carbon-manganese steel pipes*

c is obtained from *Table 10.2.2 Values of **c** for steel pipes* .

2.2.4 For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with *Table 10.2.2 Values of **c** for steel pipes* .

Table 10.2.1 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, in N/mm^2	Maximum permissible stress, in N/mm^2					
	Maximum design temperature, in °C					
	50	100	150	200	250	300
320	107	105	99	92	78	62
360	120	117	110	103	91	76
410	136	131	124	117	106	93
460	151	146	139	132	122	111
490	160	156	148	141	131	121

Table 10.2.2 Values of *c* for steel pipes

Piping service	*c*
	mm
Saturated steam systems	0,8
Steam coil systems in cargo tanks	2,0
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow down (for boilers) systems	1,5
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Fuel oil systems	1,0
Cargo oil systems	2,0
Refrigerating plants	0,3
Fresh water systems	0,8
Water systems in general	3,0
(ballast & cooling water)	
Cargo pipes of ships carrying liquefied natural or petroleum gases	0,3

2.2.5 Where the pipes are efficiently protected against corrosion, the corrosion allowance may be reduced by not more than 50 per cent.

2.2.6 Discharge pipes, except filling pipes of tanks, are not to pass though void spaces which are permanently sealed, as mentioned in *Pt 5, Ch 11, 3.1 General 3.1.4*. The filling pipes of tanks are to have a thickness of not less than 6,3 mm in accordance with *Table 10.2.3 Minimum thickness for steel pipes*.

2.2.7 The minimum thickness, t_{b}, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_{b} would not reduce the thickness below t at any point after bending:

$$t_{b} = \left[\left(\frac{pD}{20\,\sigma\,e + p}\right)\left(1 + \frac{D}{2.5\mathrm{R}}\right) + c\right]\frac{100}{100 - a}\ \mathrm{mm}$$

where

p, *D*, *R*, *e*, *b* and a are as defined in *Pt 5, Ch 10, 1.2 Design symbols 1.2.1*

σ is defined in *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.1*, and *c* is to be obtained from *Table 10.2.2 Values of **c** for steel pipes*

In general, *R* is to be not less than 3*D*.

2.2.8 Where the minimum thickness calculated by *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.4* or *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.5* is less than that shown in *Table 10.2.3 Minimum thickness for steel pipes*, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance, corrosion or reduction in thickness due to bending on this nominal thickness. For larger diameters, the minimum thickness will be specially considered. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

Table 10.2.3 Minimum thickness for steel pipes

External diameter, *D*, mm	Minimum pipe thickness, mm	Air and sounding pipes for structural tanks, mm
10,2 - 12	1,6	--
13,5 - 19	1,8	--
20 - 44,5	2,0	4,5
48,3 - 63,5	2,3	4,5
70 - 82,5	2,6	4,5
88,9 - 108	2,9	4,5
114,3 - 127	3,2	4,5
133 - 139,7	3,6	4,5
152,4 - 168,3	4,0	4,5
177,8	4,5	5,0
193,7	4,5	5,4
219,1	4,5	5,9
244,5 - 273	5,0	6,3
298,5 - 368	5,0	6,3

406,4 - 457,2	6,3	6,3

Note 1. The thickness of bilge, ballast and general outboard water systems is to be not less than 4,0 mm.

Note 2. The thickness of bilge, air, overflow and sounding pipes through ballast and fuel oil tanks, ballast lines through fuel oil tanks and fuel oil lines through ballast tanks is to be not less than 6,3 mm.

Note 3. For air bilge, ballast, fuel oil, overflow, sounding, and venting pipes as mentioned in Notes 1 to 2, where the pipes are efficiently protected against corrosion, the thickness may be reduced by not more than 1 mm.

Note 4. For air and sounding pipes, the minimum thickness applies to the part of the pipe outside the tank but not exposed to the weather. The section of pipe exposed to the weather is required to be suitably increased in thickness or in compliance with the requirements of the relevant Authorities.

2.3 Pipe joints - General

2.3.1 Joints in pressure pipelines may be made by:

- Welded-on bolted flanges, *see Pt 5, Ch 10, 2.5 Welded-on flanges, butt welded joints and fabricated branch pieces*.
- Butt welds between pipes or between pipes and valve chests or other fittings, *see Pt 5, Ch 10, 2.5 Welded-on flanges, butt welded joints and fabricated branch pieces*.
- Loose Flanges, *see Pt 5, Ch 10, 2.6 Loose flanges*.
- Socket weld joints, *see Pt 5, Ch 10, 2.7 Socket weld joints*.
- Welded sleeve joints, *see Pt 5, Ch 10, 2.8 Welded sleeve joints*.
- Threaded sleeve joints, *see Pt 5, Ch 10, 2.9 Threaded sleeve joints*.
- Screwed fittings, *see Pt 5, Ch 10, 2.10 Screwed fittings*.
- Other mechanical couplings, *see Pt 5, Ch 10, 2.11 Other mechanical couplings*.
- Special types of approved joints that have been shown to be suitable for the design conditions. Details are to be submitted for consideration.

2.3.2 The dimensions and materials of flanges, gaskets and bolting, and the press-temperature rating of bolted flanges in pressure pipelines are to be in accordance with recognised national or other established standards.

2.3.3 With the welded pressure piping system referred to in *Pt 5, Ch 10, 2.3 Pipe joints - General 2.3.1* it is desirable that a few flanged joints be provided at suitable positions to facilitate installation, cold 'pull up' and inspection at Periodical Surveys.

2.3.4 Piping with joints is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

2.3.5 Consideration will be given to accepting joints in accordance with a recognized National or International Standard which is applicable to the intended service and media conveyed.

2.3.6 Where welded pipes are protected against corrosion then the corrosion protection is to be applied after welding or the corrosion protection is to be made good in way of the weld damaged area.

2.3.7 Where it is not possible to make good the corrosion protection of the weld damaged area, the pipe is to be considered to have no corrosion protection.

2.4 Steel pipe flanges

2.4.1 Flanges may be cut from plates or may be forged or cast. The material is to be suitable for the design temperature.

2.4.2 Flange attachments to pipes and pressure-temperature ratings in accordance with National or other approved Standards will be accepted.

2.5 Welded-on flanges, butt welded joints and fabricated branch pieces

2.5.1 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

2.5.2 Typical examples of welded-on flange attachments are shown in *Figure 10.2.1 Typical welded-on flanges*(a) to (f). Types (c) and (e), however, are not to be used for pipes having a bore of less than 75 mm.

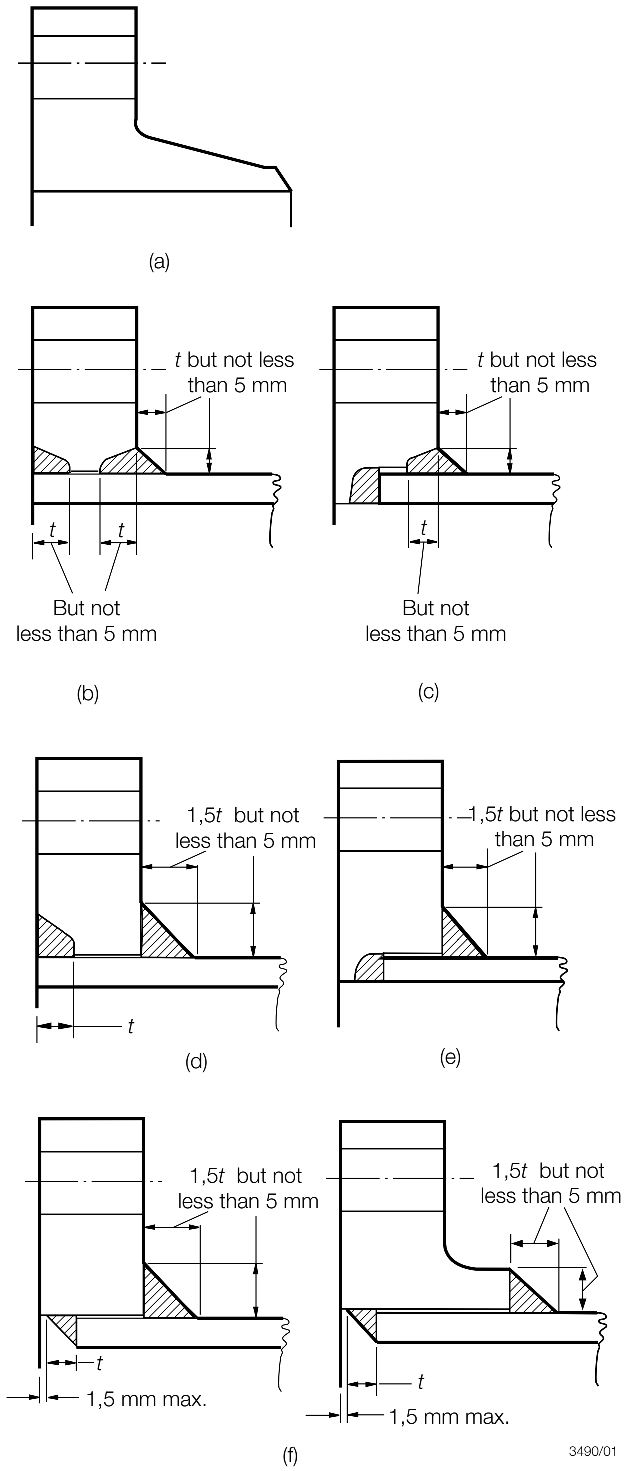


Figure 10.2.1 Typical welded-on flanges

2.5.3 Butt welded joints are generally to be of the full penetration type and are to meet the requirements of *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

2.5.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

2.5.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

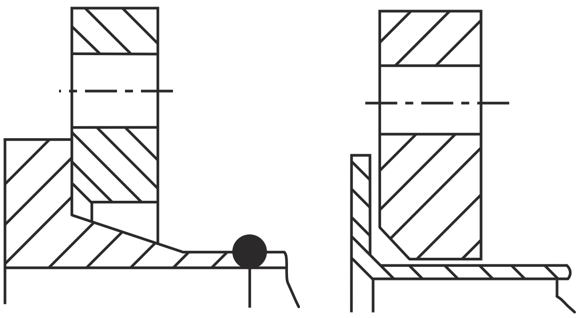
2.5.6 Where backing rings are used with flange type (a), they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same materials as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

2.5.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or, alternatively, that the thicknesses of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

2.5.8 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of *Pt 5, Ch 14 Requirements for Fusion Welding of Pressure Vessels and Piping*.

2.6 Loose flanges

2.6.1 Loose flange designs as shown in *Figure 10.2.2 Loose flange arrangements* may be used, provided they are in accordance with a recognized National or International Standard.



(a) (b)

Figure 10.2.2 Loose flange arrangements

2.6.2 Loose flange designs where the pipe end is flared as shown in *Figure 10.2.2 Loose flange arrangements*(b) are only to be used for water pipes and on open ended lines.

2.7 Socket weld joints

2.7.1 Socket weld joints may be used in Class III systems with carbon steel pipes of any outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. In particular cases, socket welded joints may be permitted for piping systems of Class I and II, having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

2.7.2 The thickness of the socket weld fittings is to meet the requirements of *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.4* but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametral clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided

between the end of the pipe and the bottom of the socket. *See also Ch 13, 5.2 Manufacture and workmanship 5.2.9* of the Rules for Materials.

2.7.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

2.8 Welded sleeve joints

2.8.1 Welded sleeve joints may be used in Class III systems with carbon steel pipes of any outside diameter. In particular cases, welded sleeve joints may be permitted for piping systems of Class I and II, having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

2.8.2 Sleeve joints are not to be used in the following locations:

- Bilge pipes in way of deep tanks.
- Air and sounding pipes passing through cargo tanks.

2.8.3 Welded sleeve joints may be used in piping systems for the storage, distribution and utilisation of fuel oil, lubricating or flammable oil systems in machinery spaces provided they are located in readily visible and accessible positions. *See also Pt 5, Ch 12, 2.6 Precautions against fire 2.6.2*.

2.8.4 The thickness of the sleeve is to satisfy the requirements of *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.4*and *Table 10.2.3 Minimum thickness for steel pipes* but is to be not less than 1,42 times the nominal thickness of the pipe in order to satisfy the throat thickness required in *Pt 5, Ch 10, 2.8 Welded sleeve joints 2.8.5*. The radial clearance between the outside diameter of the pipe and the internal diameter of the sleeve is not to exceed 1 mm for pipes up to a nominal diameter of 50 mm, 2 mm on diameters up to 200 mm nominal size and 3 mm for larger size pipes. The pipe ends are to be separated by a clearance of approximately 2 mm at the centre of the sleeve. Alternatively, consideration will be given to sleeve thickness in accordance with a relevant National Standard.

2.8.5 The sleeve material is to be compatible with the associated piping and the leg lengths of the fillet weld connecting the pipe to the sleeve are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

2.8.6 The minimum length of the sleeve is to conform to the following formula:

$$L_{si} = 0{,}14D + 36 \text{ mm}$$

where

L_{si} is the length of the sleeve

D is defined in *Pt 5, Ch 10, 1.2 Design symbols 1.2.1*.

2.9 Threaded sleeve joints

2.9.1 Threaded sleeve joints, in accordance with national or other established standards, may be used with carbon steel pipes within the limits given in *Table 10.2.4 Limiting design conditions for threaded sleeve joints*. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where flammable or toxic media is conveyed.

Table 10.2.4 Limiting design conditions for threaded sleeve joints

Thread type	Outside pipe diameter, in mm		
	Class I	Class II	Class III
Tapered thread	<33,7	<60,3	<60,3
Parallel thread	–	–	<60,3

2.10 Screwed fittings

2.10.1 Screwed fittings, including compression fittings, of an approved type may be used in piping systems for pipes not exceeding 51 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then LR may require the fittings to be subjected to special tests to demonstrate their suitability for the intended service and working conditions.

2.11 Other mechanical couplings

2.11.1 Pipe unions, compression couplings, or slip-on joints, as shown in *Figure 10.2.3 Examples of mechanical joints (Part 1)* and *Figure 10.2.4 Examples of mechanical joints (Part 2)* may be used if Type Approved for the service conditions and the intended application. The Type Approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in *Table 10.2.5 Application of mechanical joints* and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in *Table 10.2.6 Application of mechanical joints depending on class of piping*.

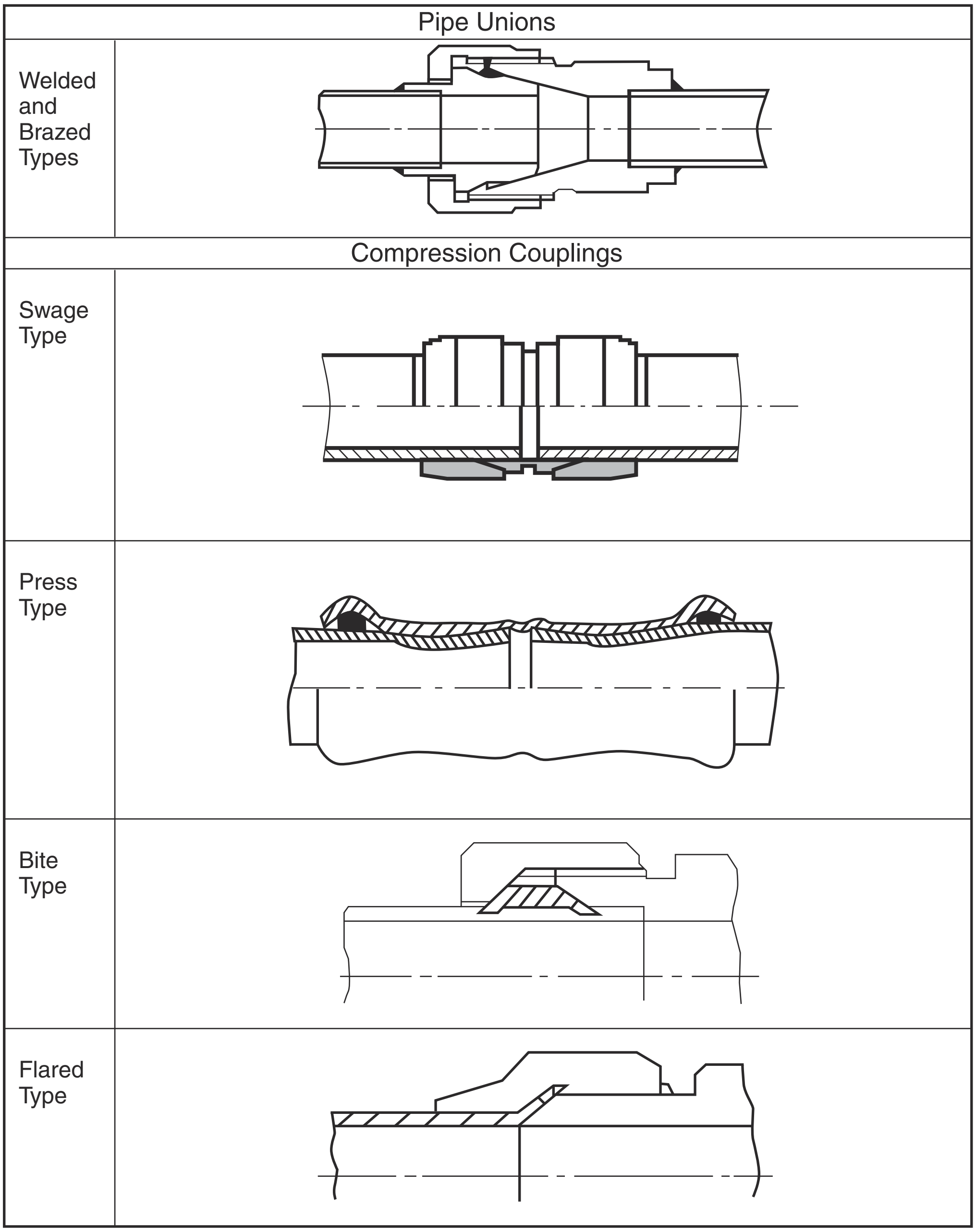


Figure 10.2.3 Examples of mechanical joints (Part 1)

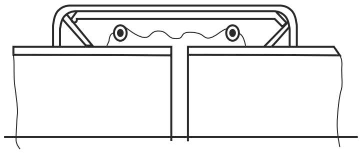
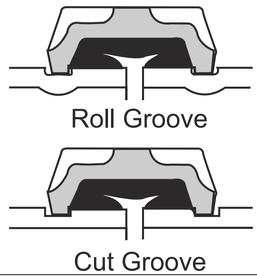
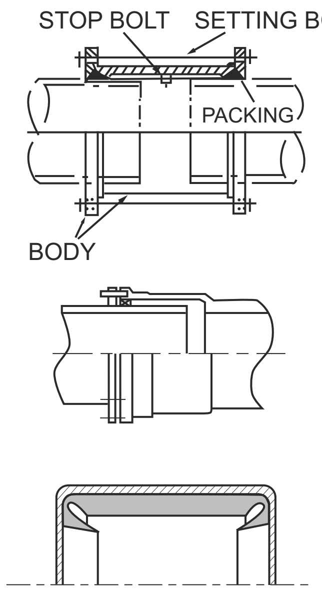
Slip-on Joints	
Grip Type	
Machine Grooved Type	
SlipType	

Figure 10.2.4 Examples of mechanical joints (Part 2)

Table 10.2.5 Application of mechanical joints

Systems	Kind of connections			Classification of pipe system	Fire endurance test condition, *see* Note 7
	Pipe unions	Compression couplings	Slip-on joints		
Flammable fluids (flash point ≤ 55°C)					
Cargo oil lines, *see* Note 4	+	+	+	dry	30 min dry (*)
Crude oil washing lines, *see* Note 4	+	+	+	dry	30 min dry (*)

Vent lines, *see* Note 3	+	+	+	dry	30 min dry (*)
Inert gas					
Water seal effluent lines	+	+	+	wet	30 min wet (*)
Scrubber effluent lines	+	+	+	wet	30 min wet (*)
Main lines, *see* Notes 2 & 4	+	+	+	dry	30 min dry (*)
Distribution lines, *see* Note 4	+	+	+	dry	30 min dry (*)
Flammable fluids (flash point > 55°C)					
Cargo oil lines, *see* Note 4	+	+	+	dry	30 min dry (*)
Fuel oil lines, *see* Notes 2 & 3	+	+	+	wet	30 min wet (*)
Lubricating oil lines, *see* Notes 2 & 3	+	+	+	wet	
Hydraulic oil, *see* Notes 2 & 3	+	+	+	wet	
Thermal oil, *see* Notes 2 & 3	+	+	+	wet	
Sea water					
Bilge lines, *see* Note 4	+	+	+	dry/wet	8 min dry + 22 min wet (*)
Permanent water filled fire-extinguishing systems, e.g. fire main, sprinkler systems, *see* Note 3	+	+	+	wet	30 min wet (*)
Non-permanent water filled fire-extinguishing systems, e.g. foam, drencher systems and fire main, *see* Note 3	+	+	+	dry/wet	8 min dry + 22 min wet (*)
Ballast system, *see* Note 1	+	+	+	wet	30 min wet (*)
Cooling water system, *see* Note 1	+	+	+	wet	30 min wet (*)
Tank cleaning services	+	+	+	dry	Fire endurance test not required
Non-essential systems	+	+	+	dry, dry/wet, wet	Fire endurance test not required

Fresh water					
Cooling water system, *see* Note 1	+	+	+	dry	Fire endurance test not required
Condensate return, *see* Note 1	+	+	+	dry	
Non-essential system	+	+	+	dry	
Sanitary/drains/scuppers					
Deck drains (internal), *see* Note 6	+	+	+	dry	Fire endurance test not required
Sanitary drains	+	+	+	dry	
Scuppers and discharge (overboard)	+	+	-	dry	
Sounding/vent					
Water tanks/dry spaces	+	+	+	dry, wet	Fire endurance test not required
Oil tanks (f.p. > 55°C), *see* Notes 2 & 3	+	+	+	dry	
Miscellaneous					
Starting/control air, *see* Note 1	+	+	-	dry	30 min dry (*)
Service air (non-essential)	+	+	+	dry	Fire endurance test not required
Brine	+	+	+	wet	
CO_2 system (outside protected space), *see* Note 1	+	+	-	dry	30 min dry (*)
CO_2 system (inside protected space)	+	+	-	dry	Mechanical joints shall be constructed of materials with a melting point above 925°C.
Steam	+	+	+ *see* Note 5	wet	Fire endurance test not required

Abbreviations: + Application is allowed. - Application is not allowed. * Fire endurance test as specified in LR's *Test Specification No. 2, Ch 5, Appendix 4 – Mechanical pipe joints – Fixed connections, 4.2.7*. Note *1*. Mechanical joints that include any components which readily deteriorate in case of fire, are to be of an approved fire-resistant type when fitted in machinery spaces of category A. Mechanical couplings fitted on the 'bilge main' in machinery spaces of category A are to be of steel or equivalent material. Note *2*. Mechanical joints that include any components which readily deteriorate in case of fire are not permitted in machinery spaces of category A or accommodation spaces. Mechanical joints that include any components which readily deteriorate in case of fire that are of an approved fire-resistant type may be fitted in other machinery spaces provided the joints are located in easily visible and accessible positions. Note *3*. Mechanical joints that include any components which readily deteriorate in case of fire fitted on fuel oil lines are to be of an approved fire-resistant type. Mechanical joints that include any components which readily deteriorate in case of fire fitted on other systems are to be of an approved fire-resistant type except when fitted on open decks having little or no fire risk. Note *4*. Mechanical joints that include any components which readily deteriorate in case of fire are to be of an approved fire-resistant type when fitted in pump-rooms and on open decks. Note *5*. *See Pt 5, Ch 10, 2.11 Other mechanical couplings 2.11.10*. Note *6*. Mechanical joints are only permitted above bulkhead deck of passenger ships and freeboard deck of cargo ships. Note *7*. A category A machinery space is a machinery space containing internal combustion machinery for main propulsion or internal combustion machinery used for purposes other than main propulsion where such machinery has a total power of not less than 375 kW, or containing any oil-fired boiler or fuel oil unit, or any other oil-fired equipment other than boilers.

Table 10.2.6 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
KEY + Application is allowed – Application is not allowed			

2.11.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.11.3 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

2.11.4 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar, the required burst pressure will be specially considered.

2.11.5 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the ship's side below the bulkhead deck of passenger ships and freeboard deck of cargo ships or tanks containing flammable fluids.

2.11.6 The mechanical joints are to be designed to withstand internal and external pressure as applicable and, where used in suction lines, are to be capable of operating under vacuum.

2.11.7 The number of mechanical joints in flammable fluid systems is to be kept to a minimum. In general, flanged joints are to conform to a recognised standard.

2.11.8 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

2.11.9 Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

2.11.10 Restrained slip-on joints are permitted in steam pipes with a design pressure of 10 bar or less on the weather decks of oil and chemical tankers to accommodate axial pipe movement, *see Pt 5, Ch 11, 2.7 Provision for expansion*.

2.11.11 Mechanical joints are to be tested in accordance with the test requirements in LR's Type Approval Test Specification Number 2, as relevant to the service conditions and the intended application. The programme of testing is to be agreed with LR.

2.12 Non-destructive testing

2.12.1 For details of non-destructive tests on piping systems, other than hydraulic tests, *see Ch 13 Requirements for Welded Construction* of the Rules for Materials.

■ *Section 3* Copper and copper alloys

3.1 Copper and copper alloy pipes, valves and fittings

3.1.1 Materials for Class I and Class II piping systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of *Ch 9 Copper Alloys* of the Rules for Materials. *See also Pt 5, Ch 10, 1.6 Materials*.

3.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Specifications. The manufacturer's certificate will be acceptable and is to be provided for each consignment of material. *See Ch 1, 3.1 General 3.1.3.(c)* of the Rules for Materials.

3.1.3 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressings or other approved fabrications.

3.1.4 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding are to be carried out to the satisfaction of the Surveyor.

3.1.5 Where silver brazing is used, strength is to be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet brace at the back of the flange or at the face is undesirable. The alloy used for silver brazing is to contain not less than 49 per cent silver.

3.1.6 The use of copper-zinc brazing alloy is not permitted.

3.1.7 In general, the maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of *Ch 9 Copper Alloys* of the Rules for Materials may be accepted up to 260°C.

3.1.8 The minimum thickness, *t*, of straight copper and copper alloy pipes is to be determined by the following formula:

$$t_{\text{b}} = \left(\frac{pD}{20\,\sigma + p} + c\right)\frac{100}{100 - a}\ \text{mm}$$

where

p, *D* and *a* are as defined in *Pt 5, Ch 10, 1.2 Design symbols 1.2.1*

σ = maximum permissible design stress, in N/mm^2, from *Table 10.3.1 Copper and copper alloy pipes*. Intermediate values of stresses may be obtained by linear interpolation

c = corrosion allowance

= 0,8 mm for copper, aluminium brass, and coppernickel alloys where the nickel content is less than 10 per cent

= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater

= 0 where the media is non-corrosive relative to the pipe material.

Table 10.3.1 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2	Permissible stress, N/mm^2										
			Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	–	–	–	–
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	–	–	–	–
90/10 Copper- nickel-iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

3.1.9 The minimum thickness, t_{b}, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than tb, would not reduce the thickness below t at any point after bending:

$$t_{\text{b}} = \left[\left(\frac{pD}{20\,\sigma + p}\right)\left(1 + \frac{D}{2.5R}\right) + c\right]\frac{100}{100 - a}\ \text{mm}$$

where

p, *D*, *R*, *b* and a are as defined in *Pt 5, Ch 10, 1.2 Design symbols 1.2.1*

σ and *c* are as defined in *Pt 5, Ch 10, 3.1 Copper and copper alloy pipes, valves and fittings 3.1.7*

In general, *R* is to be not less than 3*D*.

Table 10.3.2 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter), in mm	Minimum overriding nominal thickness, in mm	
	Copper	Copper alloy

8	to	10	1,0	0,8
12	to	20	1,2	1,0
25	to	44,5	1,5	1,2
50	to	76,1	2,0	1,5
88,9	to	108	2,5	2,0
133	to	159	3,0	2,5
193,7	to	267	3,5	3,0
273	to	457,2	4,0	3,5
508	and over		4,5	4,0

3.1.10 Where the minimum thickness calculated by *Pt 5, Ch 10, 3.1 Copper and copper alloy pipes, valves and fittings 3.1.7* or *Pt 5, Ch 10, 3.1 Copper and copper alloy pipes, valves and fittings 3.1.8* is less than shown in *Table 10.3.2 Minimum thickness for copper and copper alloy pipes*, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance or reduction in thickness due to bending on this nominal thickness.

3.2 Heat treatment

3.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 4* Cast iron

4.1 Spheroidal or nodular graphite cast iron

4.1.1 Spheroidal or nodular graphite iron may be accepted for bilge, ballast and cargo oil piping.

4.1.2 Spheroidal or nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of 5,65 $\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

4.1.3 Castings for Class II and Class III systems are to comply with the requirements of acceptable national specifications. A manufacturer's certificate will be accepted and is to be provided for each consignment of material, *see also Pt 5, Ch 10, 1.6 Materials* and *Ch 1, 3.1 General 3.1.3.(c)* of the Rules for Materials.

4.1.4 Where the elongation is less than the minimum required by*Pt 5, Ch 10, 4.1 Spheroidal or nodular graphite cast iron 4.1.2*, the material is, in general, to be subject to the same limitations as grey cast iron.

4.2 Grey cast iron

4.2.1 Grey case iron pipes, valves and fittings will, in general, be accepted in Class III piping systems except as stated in *Pt 5, Ch 10, 4.2 Grey cast iron 4.2.3*.

4.2.2 Grey cast iron valves and fittings may be accepted in Class II steam systems, provided that the design pressure and temperature do not exceed 13 bar and 220°C, respectively.

4.2.3 Grey cast iron is not to be used for the following:

- Pipes for steam systems and pipes, valves and fittings for fire-extinguishing systems.
- Pipes, valves and fittings for boiler blow-down systems.
- Ship-side valves and fittings, *see Pt 5, Ch 11, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)*.
- Valves fitted on the collision bulkhead, *see Pt 5, Ch 11, 3.5 Fore and after peaks*.

- Bilge lines in tanks.
- Pipes and fittings in flammable oil and thermal oil systems where the design pressure exceeds 10 bar or the design operating temperature is greater than 80°C.
- Valves fitted to tanks containing flammable oil under static pressure.
- Piping subject to pressure shock, excessive strains or vibrations.
- Valves chests and fittings for starting air systems, *see Pt 5, Ch 2, 8.3 Starting air pipe systems and safety fittings 8.3.3*.

4.2.4 Grey iron castings for Class III systems are to be manufactured and tested in accordance with acceptable National Specifications.

■ *Section 5* **Plastic pipes**

5.1 General

5.1.1 Proposals to use plastic pipes in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions, the intended service and location. Details are to be submitted for approval. Special consideration will be given to any proposed service for plastic pipes not mentioned in these Rules.

5.1.2 5Plastic pipes and fittings will, in general, be accepted in Class III piping systems. Proposals for the use of plastic in Class I and Class II piping systems will be specially considered.

5.1.3 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

5.1.4 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects, as referenced in *Pt 5, Ch 10, 5.4 Fire performance criteria* and *Pt 5, Ch 10, 5.5 Additional fire performance criteria applicable to inland waterways vessels*, are to be considered.

5.1.5 The use of plastic pipes may be restricted by statutory requirements of the National Authority of the country in which the vessel is to be registered.

5.2 Design and performance criteria

5.2.1 Pipes and fittings are to be of robust construction and are to comply with an acceptable National or International standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

5.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of *Pt 5, Ch 10, 5.3 Design strength*.

5.2.3 Depending on the service and location, the fire safety aspects, such as fire endurance, flame spread, smoke generation, toxicity and fire protection coatings, are to meet the requirements of *Pt 5, Ch 10, 5.4 Fire performance criteria* and *Pt 5, Ch 10, 5.5 Additional fire performance criteria applicable to inland waterways vessels*.

5.2.4 Plastic piping, connections and fittings are to be electrically conductive when:

(a) carrying fluids capable of generating electrostatic charges; or
(b) passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build-up of electrostatic charges are to be provided in accordance with the requirements of *Pt 5, Ch 10, 5.6 Electrical conductivity*.

5.3 Design strength

5.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

5.3.2 The nominal internal pressure, p_{Ni}, of the pipe is to be determined by the lesser of the following:

$$p_{Ni} \leq \frac{p_{st}}{4}$$

$$p_{\text{Ni}} \leq \frac{p_{\text{lt}}}{4}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar

p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar

Failure pressures obtained over a reduced period and extrapolated in accordance with a recognised National or International Standard will be specially considered.

5.3.3 In service, the pipe is not to be subjected to a pressure greater than p_{Ni}.

5.3.4 The nominal external pressure, p_{Ne}, of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$p_{\text{Ne}} \leq \frac{p_{\text{col}}}{3}$$

where

p_{col} = pipe collapse pressure, in bar

5.3.5 p_{col} is not to be less than 3 bar.

5.3.6 Piping is to meet the requirements of *Pt 5, Ch 10, 5.3 Design strength* over the range of service temperature which will be experienced in service.

5.3.7 High temperature limits and pressure reductions relative to nominal pressures are to be in accordance with a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature for deflection under load of the resin or plastic material without reinforcement. The minimum heat distortion temperature is not to be less than 80°C. *See also Ch 14, 4 Plastic pipes and fittings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

5.3.8 Where it is proposed to use plastic piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

5.3.9 The selection of plastic materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

5.3.10 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

5.4 Fire performance criteria

5.4.1 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

5.4.2 The materials used for plastic pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts are to have low flame spread characteristics.

5.4.3 The materials used for plastic pipes within accommodation, service and control spaces are not to be capable of producing excessive quantities of smoke and toxic products that may be a hazard to personnel within those spaces.

5.5 Additional fire performance criteria applicable to inland waterways vessels

5.5.1 Where plastic pipes are used in systems essential to the safe operation of the vessel, or for containing combustible liquids or sea water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings, including couplings with flexible internal seals, are to be of a type which has been fire endurance tested in accordance with the requirements of *Table 10.5.1 Fire endurance requirements*.

Table 10.5.1 Fire endurance requirements

		Location										
		A	B	C	D	E	F	G	H	I	J	K
CARGO (FLAMMABLE CARGOES (f.p. ≤55°C))												
1	Cargo lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
2	Crude oil washing lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
3	Vent lines	N/A	N/A	N/A	N/A	N/A	0	N/A	0[10]	0	N/A	X
INERT GAS												
4	Water seal effluent line	N/A	N/A	0[1]	N/A	N/A	0[1]	0[1]	0[1]	0[1]	N/A	0
5	Scrubber effluent line	0[1]	0[1]	N/A	N/A	N/A	N/A	N/A	0[1]	0[1]	N/A	0
6	Main line	0	0	L1	N/A	N/A	N/A	N/A	N/A	0	N/A	L1[6]
7	Distribution lines	N/A	N/A	L1	N/A	N/A	0	N/A	N/A	0	N/A	L1[2]
FLAMMABLE LIQUIDS (f.p. >55°C)												
8	Cargo lines	X	X	L1	X	X	N/A[3]	0	0[10]	0	N/A	L1
9	Fuel oil	X	X	L1	X	X	N/A[3]	0	0	0	L1	L1
10	Lubricating oil	X	X	L1	X	X	N/A	N/A	N/A	0	L1	L1
11	Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
OUTBOARD WATER[1]												
12	Bilge main and branches	L1[7]	L1[7]	L1	X	X	N/A	0	0	0	N/A	L1
13	Fire main and water spray	L1	L1	L1	X	N/A	N/A	N/A	0	0	X	L1
14	Foam system	L1W	L1W	L1W	N/A	N/A	N/A	N/A	N/A	0	L1W	L1W
15	Sprinkler system	L1W	L1W	L3	N/A	N/A	N/A	N/A	0	0	L3	L3
16	Ballast	L3	L3	L3	L3	X	0[10]	0	0	0	L2W	L2W
17	Cooling water, essential services	L3	L3	N/A	N/A	N/A	N/A	N/A	0	0	N/A	L2W
18	Tank cleaning services fixed machines	N/A	N/A	L3	N/A	N/A	0	N/A	0	0	N/A	L3[2]
19	Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
FRESHWATER												
20	Cooling water essential services	L3	L3	N/A	N/A	N/A	N/A	0	0	0	L3	L3
21	Condensate return	L3	L3	L3	0	0	N/A	N/A	N/A	0	0	0

22	Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
SANITARY/DRAINS/ SCUPPERS												
23	Deck drains (internal)	L1W[4]	L1W[4]	N/A	L1W[4]	0	N/A	0	0	0	0	0
24	Sanitary drains (internal)	0	0	N/A	0	0	N/A	0	0	0	0	0
25	Scuppers and discharges (overboard)	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0	0	0	0	0[1,8]	0
SOUNDING/AIR												
26	Water tanks/dry spaces	0	0	0	0	0	0[10]	0	0	0	0	0[10]
27	Oil Tanks (f.p. > 55°C)	X	X	X	X	X	X[3]	0	0[10]	0	X	X
MISCELLANEOUS												
28	Control air	L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	N/A	0	0	0	L[15]	L[15]
29	Service air (non-essential)	0	0	0	0	0	N/A	0	0	0	0	0
30	Brine	0	0	N/A	0	0	N/A	N/A	N/A	0	0	0
31	Auxiliary low pressure steam (≤ 0,7 MPa)	L2W	L2W	0[9]	0[9]	0[9]	0	0	0	0	0[9]	0[9]
NEW SERVICES												
32	Central vacuum cleaners	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A	0	0	0
33	Exhaust gas cleaning system effluent line	L3[1]	L3[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	L3[1,11]/N/A	N/A
34	Urea transfer/ supply system (SCR installations)	L1[12]	L1[12]	N/A	N/A	N/A	N/A	N/A	N/A	0	L3[1,11]/N/A	N/A
LOCATION DEFINITIONS												
	Location	Definitions										
A	Machinery spaces of Category A	Machinery spaces of Category A as defined in *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.19.										
B	Other machinery spaces and pump rooms	Spaces, other than Category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilising, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.										
C	Cargo pump rooms	Spaces containing cargo pumps and entrances and trunks to such spaces.										
D	Ro-ro cargo holds	Ro-Ro cargo holds are Ro-Ro cargo spaces and special category spaces as defined in *SOLAS - International Convention for the Safety of Life at SeaChapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.14 and *SOLAS - International Convention for the Safety of Life at SeaChapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.18.										

E	Other dry cargo holds	All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.
F	Cargo tanks	All spaces used for liquid cargo and trunks to such spaces.
G	Fuel oil tanks	All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.
H	Ballast water tanks	All spaces used for ballast water and trunks to such spaces.
I	Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
J	Accommodation, service	Accommodation spaces, service spaces and control stations as defined in *SOLAS - International Convention for the Safety of Life at SeaChapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.10, *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.12 and *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.22.
K	Open decks	Open deck spaces, as defined in *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction/9.2.2.3(5)*.
ABBREVIATIONS		
L1	Level 1. Piping having passed the fire endurance test specified in Appendix 1 of *IMO Resolution A.753(18) - Guidelines for the Application of Plastic Pipes on Ships - (adopted on 4 November 1993)Amended by Resolution MSC.313(88)*, as amended by *Resolution MSC.313(88) – Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)) – (Adopted on 26 November 2010)* and *Resolution MSC.399(95) - Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)), as amended by Resolution MSC.313(88) - (Adopted on 5 June 2015)* for a duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1). Level 1W –Piping systems similar to Level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable (L1W).	
L2	Level 2. Piping having passed the fire endurance test specified in Appendix 1 of *IMO Resolution A.753(18) - Guidelines for the Application of Plastic Pipes on Ships - (adopted on 4 November 1993)Amended by Resolution MSC.313(88)*, as amended by *Resolution MSC.313(88) – Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)) – (Adopted on 26 November 2010)* and *Resolution MSC.399(95) - Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)), as amended by Resolution MSC.313(88) - (Adopted on 5 June 2015)* for a duration of a minimum of 30 minutes in the dry condition is considered to meet level 2 fire endurance standard (L2). Level 2W – Piping systems similar to Level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable (L2W).	
L3	Fire endurance test in wet conditions, 30 minutes, *IMO Resolution A.753(18) - Guidelines for the Application of Plastic Pipes on Ships - (adopted on 4 November 1993)Amended by Resolution MSC.313(88) Appendix 2 - Test Method for Fire Endurance Testing of Water-Filled Plastic Piping*.	
0	No fire endurance test required.	
N/A	Not applicable.	

X	Metallic materials having a melting point greater than 925°C.
Note 1. Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space). Note 2. Remote closing valves to be provided at the cargo tanks. Note 3. When cargo tanks contain flammable liquids with f.p. > 55°C, '0' may replace 'N/A' or 'X'. Note 4. For drains serving only the space concerned, '0' may replace 'L1W'. Note 5. When controlling functions are not required by the Rules or statutory requirements, '0' may replace 'L1'. Note 6. For pipe between machinery space and deck water seal, '0' may replace 'L1'. Note 7. For passenger vessels, 'X' is to replace 'L1'. Note 8. Scuppers serving open decks should be 'X' throughout. Note 9. For essential services, such as fuel oil tank heating and ship's whistle, 'X' is to replace '0'. Note 10. Air and sounding pipes on open deck are to be of substantial construction, *see also Pt 5, Ch 11, 10.2 Materials 10.2.1*. Note 11. L3 in service spaces, NA in accommodation and control spaces. Note 12. Type Approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire. Note 13. For Passenger Ships subject to SOLAS II-2, Reg.21.4 (Safe return to Port), plastic pipes for services required to remain operative in the part of the ship not affected by the casualty thresholds, such as systems intended to support safe areas, are to be considered essential services. In accordance with *MSC.1/Circular.1369 – Interim Explanatory Notes for the Assessment of Passenger Ship Systems' Capabilities After a Fire or Flooding Casualty– (22 June 2010)1*, interpretation 12, for Safe Return to Port purposes, plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.	

5.6 Electrical conductivity

5.6.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc. is not to exceed 0,1 MΩ/m.

5.6.2 Where a piping system is required to be electrically conductive for the control of static electricity, electrical continuity is to be maintained across the joints and fittings and the system is to be earthed. The resistance to earth from any point in the piping system is not to exceed 1 MΩ. *See also Pt 6, Ch 2, 1.7 Earthing*.

5.7 Manufacture and quality control

5.7.1 All materials for plastic pipes and fittings are to be approved by LR, and are in general to be tested in accordance with *Ch 14, 4 Plastic pipes and fittings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by *Ch 14, 4.9 Hydraulic test* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* may be replaced by testing carried out in accordance with the requirements stipulated in a recognised National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided that there is an effective quality system in place complying with the requirements of *Ch 14, 4.4 Quality assurance* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* and the testing is completed to the satisfaction of the LR Surveyor.

5.7.2 The material manufacturer's test certificate, based on actual tested data, is to be provided for each batch of material.

5.7.3 Plastic pipes and fittings are to be manufactured at a works approved by LR in accordance with agreed quality control procedures which shall be capable of detecting at any stage (e.g. incoming material, production, finished article, etc.) deviations in the material, product or process.

5.7.4 Plastic pipes are to be manufactured and tested in accordance with *Ch 14, 4 Plastic pipes and fittings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*. For Class III piping systems the pipe manufacturer's test certificate may be accepted in lieu of an LR Certificate and is to be provided for each consignment of pipe.

5.8 Construction and installation

5.8.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.8.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding, laminating and adhesive bonding.

5.8.3 Where bonding systems are used, the manufacturer or installer shall provide a written procedure covering all aspects of installation, including temperature and humidity conditions. The bonding procedure is to be approved by LR.

5.8.4 The person carrying out the bonding is to be qualified. Records are to be available to the Surveyor for each qualified person showing the bonding procedure and performance qualification, together with dates and results of the qualification testing.

5.8.5 Conditions during installation, such as temperature and humidity, which may affect the strength of the finished joints, are to be in accordance with the agreed bonding procedure.

5.8.6 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastic and metallic pipes.

5.8.7 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead or deck pieces. The bulkhead or deck pieces are to be of substantial construction and suitably protected against corrosion and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to *Pt 5, Ch 10, 5.8 Construction and installation* . Details of the arrangements are to be submitted for approval.

5.8.8 Pipes or other fittings attached directly to the plating of tanks and to bulkheads, which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead or tank pieces may be welded to the plating.

5.9 Additional requirements for testing plastic pipes for inland waterways vessels

5.9.1 Where a piping system is required to be electrically conductive, tests are to be carried out in accordance with *Pt 5, Ch 10, 5.6 Electrical conductivity*

5.9.2 The hydraulic testing of pipes and fittings is to be in accordance with *Pt 5, Ch 10, 8 Hydraulic tests on pipes and fittings*.

5.9.3 In the case of pipes intended for essential services each qualified person is, at the place of construction, to make at least one test joint, representative of each type of joint to be used. The joined pipe section is to be tested to an internal hydrostatic pressure of four times the design pressure of the pipe system and the pressure held for not less than one hour, with no leakage or separation of joints. The bonding procedure test is to be witnessed by the Surveyor.

■ *Section 6* Valves

6.1 Design requirements

6.1.1 The design, construction and operational capability of valves is to be in accordance with an acceptable National or International Standard appropriate to the piping system. Where valves are not in accordance with an acceptable standard, details are to be submitted for consideration. Where valves are fitted, the requirements of*Pt 5, Ch 10, 6.1 Design requirements 6.1.2* are to be satisfied.

6.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

6.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

6.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their controlgear, are to be of steel construction or of an acceptable fire tested design.

6.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious.

6.1.6 Valves and cocks are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules the valves and cocks are to be fitted in places where they are at all times readily accessible.

6.1.7 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

6.1.8 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

6.1.9 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

6.1.10 The controls of butterfly and ball valves of the "swing through type" are to be provided with suitable means (such as a gearbox) to prevent this.

6.1.11 Additional requirements for shell valves are given in *Pt 5, Ch 11, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)*.

6.1.12 Additional requirements for valves with remote control are given in *Pt 5, Ch 11, 2.3 Valves - Installation and control*

6.1.13 Where the valves are of the diaphragm type, they are not acceptable as shut-off valves at the shell plating.

6.1.14 Resiliently seated valves are not to be used in main or auxiliary machinery spaces as branch or direct bilge suction valves or as pump suction valves from the main bilge line. For exemptions of the above, resiliently seated valves may be accepted in positions indicated below, and subject to the following conditions:

(a) As pump suction valve from the main bilge line where the valve is located in the immediate vicinity of the pump and in series with a metal seated non-return valve. The non-return valve is to be fitted on the bilge main side of the resiliently seated valve.
(b) As branch suction valve where the branch is connected to a non-isolated bilge main, as per *Pt 5, Ch 11, 4.3 Branch bilge suction arrangements connected to non-isolated bilge main*, and in series with a metal seated non-return valve. The non-return valve is to be fitted at the branch side of the resiliently seated valve.
(c) When they are used in other locations and within auxiliary machinery spaces having little or no fire risk, they should be of an approved fire safe type and used in conjunction with a metal seated non-return valve.

6.1.15 Resiliently seated valves are not acceptable for use in the fire water mains unless they have been satisfactorily fire tested.

■ *Section 7* **Flexible hoses**

7.1 General

7.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

7.1.2 For the purpose of approval for the applications in*Pt 5, Ch 10, 7.2 Applications*, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

7.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for outboard water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar. The clips are to be of stainless steel and doubled at each connection. Means are to be provided to prevent the pipe from pulling out of the hose when under pressure.

7.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

7.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

7.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

7.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in *Pt 5, Ch 10, 7.2 Applications 7.2.1*.

7.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

7.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

7.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

7.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:

(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

7.1.12 For special requirements for hoses intended for use on board of Gas, Oil and Chemical Tankers, *see also Pt 5, Ch 13, 3.9 Ship's cargo hoses*.

7.2 Applications

7.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

7.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and outboard cooling water systems. In the case of outboardwater systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed, as indicated in*Pt 5, Ch 11, 2.7 Provision for expansion*.

7.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, outboard-water, fuel oil, lubricating oil, Class III steam and hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable.

7.2.4 Where synthetic rubber or plastics hoses are used for fuel oil supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

7.2.5 Flexible hoses for use in steam systems are to be of metallic construction.

7.2.6 Flexible hoses are not to be used in high pressure fuel oil injection systems.

7.2.7 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire-extinguishing systems.

7.3 Design requirements

7.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

7.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with *Pt 5, Ch 10, 2.11 Other mechanical couplings* as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

7.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by *Pt 5, Ch 10, 7.4 Testing* are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

7.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and outboard-water systems where failure may result in flooding, are to be of fire-resistant type. Non-metallic flexible hoses used for outboard-water systems and flammable media, except fuel oil, installed on open decks having little or no fire risk are not required to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

7.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

7.4 Testing

7.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

7.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

- ISO 6802 - *Rubber and plastics hoses and hose assemblies with wire reinforcements - Hydraulic impulse test with flexing.*
- ISO 6803 - *Rubber or plastics hoses and hose assemblies - Hydraulic-pressure impulse test without flexing.*
- ISO 15540 - *Ships and marine technology - Fire resistance of hose assemblies - Test methods.*
- ISO 15541 - *Ships and marine technology - Fire resistance of hose assemblies - Requirements for test bench.*
- ISO 10380 - *Pipe-work - Corrugated metal hoses and hose assemblies.*

Other standards may be accepted where agreed by LR.

7.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard* to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

NOTE

* The International Standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 8*
Hydraulic tests on pipes and fittings

8.1 Hydraulic tests before installation on board

8.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure to the Surveyor’s satisfaction. Further, all steam, feed, compressed air and fuel oil pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7,0 bar. The test is to be carried out after completion of manufacture and before installation on board and where applicable, before insulating and coating.

8.1.2 The test pressure is to be 1,5 times the design pressure, as defined in*Pt 5, Ch 10, 1.3 Design pressure*.

8.1.3 Where testing of systems or sub-systems following final assembly is specified, in addition to the requirements of *Pt 5, Ch 10, 8.1 Hydraulic tests before installation on board 8.1.2* the lowest applicable pressure as defined in this sub- Section is to be used for testing.

8.1.4 Valves and fittings non-integral with the piping system, intended for Classes I and II, are to be tested in accordance with Recognised Standards, but to not less than 1,5 times the design pressure. Where design features are such that modifications to the test requirements are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

8.1.5 All valves are to be tested for tightness at 1,1 times the maximum permissible working pressure.

8.1.6 For requirements relating to valves and cocks intended to be fitted on the ship's side below the load water line, *see Pt 5, Ch 11, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges) 2.5.7*.

8.1.7 In no case is the membrane stress to exceed 90 per cent of the yield stress at the testing temperature.

8.2 Testing after assembly on board

8.2.1 Heating coils in tanks and fuel oil piping are to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 4 bar.

8.2.2 Where pipes specified in *Pt 5, Ch 10, 8.1 Hydraulic tests before installation on board 8.1.1* are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of *Pt 5, Ch 10, 8.1 Hydraulic tests before installation on board* after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

8.2.3 The hydraulic test required by *Pt 5, Ch 10, 8.2 Testing after assembly on board 8.2.2* may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.

8.2.4 Where bilge pipes are accepted in way of double bottom tanks or deep tanks, *see Pt 5, Ch 11, 7.7 Bilge pipes in way of double bottom tanks* and *Pt 5, Ch 11, 7.8 Bilge pipes in way of deep tanks*, the pipes after fittings are to be tested by hydraulic pressure to the same pressure as the tanks through which they pass.

8.3 ***Cross-reference***

8.3.1 *See also Pt 5, Ch 11, 2.9 Testing after installation* for testing after installation.

■ *Section 9*
Piping for Type G tankers and gas fuelled ships

9.1 Scope

9.1.1 This Section is applicable to piping systems installed on Type G tankers and gas fuelled ships for the following pipes and piping system components:

(a) Pipe work: stainless steel, carbon steel and copper.
(b) Valves: normal and cryogenic service (below minus 55°C).
(c) Bellows: normal and cryogenic service (below minus 55°C).
(d) Pipe fittings: elbows, reducers, tee connections, etc.
(e) Ancillary fittings: weldolets, threadolets, thermo pockets.

9.1.2 The following piping systems are covered by this Section:

(a) LPG/LNG cargo systems: normal cargo operations.
(b) LNG cargo systems: gas burning and use of cargo as fuel.
(c) LNG Regasification system: high and low pressure.
(d) Gas storage and supply systems for gas fuelled ships.

9.1.3 In addition to the requirements of this Chapter, the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, July 2022* are to be complied with as far as they are applicable.

9.2 Application

9.2.1 The requirements of this Section apply to pipes and piping system components, such as valves, elbows and bellows, which are to be used on Type G tankers and gas fuelled ships. The requirements are also applicable to other gas cargo services such as regasification systems and gas combustion units, and are in addition to the relevant Sections of this Chapter and *Pt 5, Ch 13 Piping Systems for Ships Intended for the Carriage of Liquids in Bulk*, where appropriate.

9.3 Classes of pipe

9.3.1 The material requirements for piping systems vary depending on the Class of the piping system. The Class of the piping system is dependent on the design pressure or temperature of the system and the pipe material used, as shown in *Table 10.1.1 Maximum pressure and temperature conditions for Class II and Class III piping systems*.

9.3.2 As referred to in *Table 10.1.1 Maximum pressure and temperature conditions for Class II and Class III piping systems*, piping systems containing LPG/LNG, cargo or fuel gas as the conveyed medium are to be treated as 'Flammable liquids'. These piping systems are to be categorised as Class II. Vapour lines are also to be categorised as Class II systems but the upper limit on pressure may be increased to 40 bar in accordance with the 'Other media'. Where higher design pressures are applied, such as in a re-gasification system, liquid lines above 16 bar and vapour lines above 40 bar are to be categorised as Class I. All open-ended pipes, such as vent lines and pipes inside the cargo tanks may be categorised as Class III.

9.4 Materials

9.4.1 Stainless steel pipes, valves and fittings for welded fabrication are to be grades 304L, 316L, 321 or 347 in accordance with *Ch 6, 5 Stainless steel pressure pipes* of the Rules for Materials. For non-welded fabrications the grades 304 and 316 may be accepted.

9.4.2 The materials used in Class I and Class II systems are to be produced at a works approved by LR. Testing is to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* and Tables LR 6.1 and 6.4 in chapter 6 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, July 2022* or Table LR 7.1 and LR 7.4 in Chapter 7.4 Regulations for materials of the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, July 2022*.

9.4.3 For stainless steel pipes, valve castings and forgings intended for service temperatures down to minus 55°C, an LR materials certificate is required, unless:

- $DN < 50$ or
- $DN \leq 150$ and $DN \times P < 2500$

where a manufacturer's material certificate is acceptable.

9.4.4 For pipe systems operating at cryogenic temperatures lower than minus 55°C, an LR materials certificate is required.

9.4.5 Properties of materials other than stainless steel are to be submitted and will be specially considered.

9.5 Valves and piping components independent of temperature

9.5.1 For valves and piping components fitted in the cargo piping system of Type G tankers, each type of valve and piping component is to have evidence of satisfactory type testing.

9.6 Valves for cryogenic temperature service

9.6.1 Each size and type of valve intended to be used at a working temperature below –55ºC should be subjected to a tightness test to the minimum design temperature or lower, and to a pressure not lower than the design pressure of the valve. During the test the satisfactory operation of the valve should be ascertained. The tightness test is to be conducted in accordance with a recognised National or International Code or Standard.

9.7 Expansion bellows

9.7.1 The following plans and particulars are to be submitted:

(a) Dimensioned drawings of each type of bellows.
(b) Design calculations to show that the bellows are suitable for the intended design conditions, carried out to EJMA (Expansion Joint Manufacturers Association) standards (latest edition) or equivalent.
(c) A proposed prototype test program covering the tests detailed in *Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems* of the Rules for Ships for Liquefied Gases.
(d) Calculations to EJMA standards may be accepted, together with sample testing detailed above, in order to cover the entire size range for the type.

9.7.2 In accordance with *Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems* of the Rules for Ships for Liquefied Gases, the requirements for type testing in *Pt 5, Ch 12, 9.8 Expansion bellows 9.8.3* are to be performed on each type of expansion bellows intended for use on LPG/LNG piping.

9.7.3 For each type of expansion bellows, an element of the bellows, not pre-compressed, is to be pressure tested at not less than five times the design pressure without bursting. This test is to be conducted at room temperature on each 'type' of element and need not be the complete bellows unit. A test on one element can cover other sized bellows with the same cross-sectional bellows form. The design pressure is to be at least 10 bar; bellows fitted to safety valves and vent lines may have a minimum design pressure of 5 bar in accordance with *5.2.3 Design pressure .3* of the Rules for Ships for Liquefied Gases. The required test duration is not to be less than 5 minutes.

9.7.4 A pressure test is to be performed on each type of expansion joint complete with all the accessories such as flanges, stays and articulations, at twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation. The test is to be undertaken at the minimum design temperature, unless the bellows material is stainless steel, for which this test may be carried out at ambient temperature. The test duration is to be 30 minutes unless otherwise agreed with LR.

9.7.5 A cyclic thermal movement test, replicating the cooling down and warming up cycle which occurs during cargo loading and discharge, is to be performed on a complete expansion joint, by the application of representative external deflection resulting in bellows movement. This is successfully to withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. The number of cycles is to be estimated by the Builder and depends on the ship's intended trading pattern and life expectancy. As a minimum, testing to 7000 cycles is to be carried out. The test is to be carried out at between 2-5 cycles per second. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature. The maximum movements on the horizontal and vertical axis are to be provided by the Builders and obtained from their stress analysis; however, the test can be extended to any value which is greater than that expected, or to the maximum deflection for which the bellows unit is suitable. Movements in the test need not be in both horizontal and vertical directions, but the horizontal-vertical box diagonal distance may be used. NDE testing is required after cyclic testing.

9.7.6 A cyclic fatigue test, representing ship deformation, is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2 000 000 cycles at a frequency not higher than 5 cycles per second. The test may be waived if the piping arrangement experiences ship deformation loads. NDE is required after cyclic testing.

9.7.7 The cyclic thermal movement test and cyclic fatigue test may be waived by LR if satisfactory documentation is provided to establish the suitability of the expansion joints to withstand the expected working conditions. Where the maximum internal pressure exceeds 1,0 bar gauge, this documentation is to include sufficient test data to justify the design method used, with particular reference to correlation between calculation and test results.

9.8 Pressure testing of piping and other piping components

9.8.1 Pressure testing is to be undertaken in accordance with specific Rule requirements relating to the system in which the component is to be located.

9.8.2 The duration for which pressure tests are to be held is to be in conjunction with an applicable and recognised Code or Standard acceptable to LR.

9.9 Equipment documentation

9.9.1 A certificate is required for each piping component supplied to be fitted in a Class I or Class II system. This certification is required for each size and type of equipment delivered. A single certificate may cover a number of valves, provided that they are of the same type and size, and serial numbers have been included on the certificate. If the piping components are part of a system fitted to a skid or packaged unit, then the complete skid may be supplied with a single certificate stating that the package has been constructed using approved materials, approved and tested in accordance with LR Rule requirements.

9.10 Relief valves for LPG/LNG cargo and deck tanks

9.10.1 Relief valves fitted to cargo tanks and deck tanks are to be of a type tested design. Type testing is to include:

- flow or capacity verification to a recognised Standard acceptable to the Administration;
- cryogenic testing when operating at design temperatures colder than minus 55°C;
- seat tightness testing to a recognised Standard or manufacturer's procedure acceptable to the Administration; and
- pressure testing of pressure-containing parts to at least 5 times the design pressure.

9.10.2 The materials used for construction of relief valves fitted to cargo tanks and deck tanks are to be produced in a works approved by LR and be provided with a Lloyd's Register Material Certificate.

Section 10
Austenitic stainless steels

10.1 General

10.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of stainless steels in outboard water systems *see Pt 5, Ch 10, 11.3 Steel pipes 11.3.4*.

10.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.3* or *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.7* using a corrosion allowance of 0,8 mm. Values of the 1,0 per cent proof stress and tensile strength of the material for use in the formula in *Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.1* may be obtained from *Table 6.5.2 Mechanical properties for acceptance purposes* in Chapter 6 of the Rules for Materials.

10.1.3 Where stainless steel is used in lubricating and hydraulic oil systems, the corrosion allowance may be reduced to 0 mm. For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with *Table 12.2.3 Values of c for steel pipes* . Where the pipes are efficiently protected, the corrosion allowance may be reduced by not more than 50 per cent.

10.1.4 In no case is the thickness of the stainless steel pipes is to be less than that shown in *Table 10.10.1 Minimum thickness for austenitic stainless steel pipes*.

Table 10.10.1 Minimum thickness for austenitic stainless steel pipes

Standard pipe sizes (outside diameter) in mm			Minimum thickness, in mm
10,2	to	17,2	1,0
21,3	to	48,3	1,6
60,3	to	88,9	2,0
114,3	to	168,3	2,3
219,1			2,6
273			2,9
323,9	to	406,4	3,6
Over	406,4		4,0
Note The external diameters and thicknesses have been selected from ISO Standard 1127:1980. Diameter and thicknesses according to other National or International Standards may be accepted.			

10.1.5 Joints in stainless steel pipe work may be made by any of the techniques described in *Pt 5, Ch 10, 2.3 Pipe joints - General*.

10.1.6 Where pipe work is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and the pipe.

Section 11
Guidance notes on metal pipes for water services

11.1 General

11.1.1 These guidance notes, except where it is specifically stated, apply to outboard water piping systems.

11.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of pipework in order to obtain maximum life in service.

11.2 Material

11.2.1 Materials used in outboard water piping systems include:

- Galvanized steel.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium brass.

11.2.2 Selection of materials should be based on:

- The ability to resist general and localized corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- Compatibility with the other materials in the system, such as valve bodies and casings (e.g. in order to minimize bimetallic corrosion);
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitisation of cast iron;
- The ability to resist stress corrosion and corrosion fatigue; and
- The amenability to fabrication by normal practices.

11.3 Steel pipes

11.3.1 Steel pipes should be protected against corrosion, and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

11.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

11.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in overboard water systems, including those for bilge and ballast service.

11.3.4 Austenitic stainless steel pipes are not recommended for brackish or salt water services as they are prone to pitting, particularly in polluted waters.

11.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc. and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

11.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

11.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

11.4 Copper and copper alloy pipes

11.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

11.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean overboard water. For service with polluted river or harbour waters, copper-nickeliron alloy pipes with at least 10 per cent nickel are preferable. Alpha brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

11.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean overboard water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

11.5 Flanges

11.5.1 Where pipes are exposed to sea water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where overboard water is confined to the bores of pipes, flanges may be of the same material or of a less noble metal than that of the pipe, *see also Pt 5, Ch 10, 2.3 Pipe joints - General*.

11.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

11.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickeliron alloy pipes.

11.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea water.

11.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

11.5.6 The use of a copper-zinc brazing alloy is not permitted.

11.6 Water velocity

11.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc. selected to suit the conditions.

11.6.2 The water velocity in copper pipes should not exceed 1 m/s.

11.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

Galvanized steel	3,0 m/s
Aluminium brass	3,0 m/s
90/10 copper-nickel-iron	3,5 m/s
70/30 copper-nickel	5,0 m/s

11.7 Fabrication and installation

11.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions into the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

11.7.2 Pipe bores should be smooth and clean.

11.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

11.7.4 Pipe bends should be of as large a radius as possible, and the bore surface should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

11.7.5 The position of supports should be given special consideration in order to minimize vibration and ensure that excessive bending moments are not imposed on the pipes.

11.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

11.7.7 Strainers should be provided at the inlet to sea water systems.

11.8 Metal pipes for fresh water services

11.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion of mild steel pipes unless the hardness and PH of the water are controlled.

11.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanized, or pipes of suitable non-ferrous material used.

11.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

11.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

11.8.5 Aluminium brass has been widely used as a material for heat exchanger and condenser tubes, but its use in ‘once through’ systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to piping systems on all types of Inland Waterway Vessels except where otherwise stated.

1.1.2 Special attention is drawn to National and International technical and operational requirements of countries where the ship is registered or operating and which are outside classification as defined in these Rules.

1.1.3 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules. Consideration will also be given to the pumping arrangements of small ships and ships to be assigned class notations for special services.

1.1.4 The Rules for bilge systems for dry cargo vessels carrying dangerous goods have been derived from requirements of the European provisions concerning the international Carriage of Dangerous Goods by Inland Waterways **ADN** which assume heavy traffic on relatively narrow waterways through heavily populated areas. ADN is an abbreviation from **A**ccord européen relative au transport international des merchandises **D**angereuses par voie de **N**avigation intérieure. *See also Pt 4, Ch 1, 12 Additional requirements for ships carrying dangerous goods*.

1.1.5 Where a **DG** notation is to be assigned, the requirements of this Chapter and*Pt 4, Ch 1, 1.3 Class notation 1.3.5*, are to be complied with.

1.1.6 Piping design is to comply with *Pt 5, Ch 10 Piping Design Requirements* as applicable.

1.2 Prevention of progressive flooding in damage condition

1.2.1 For ships to which subdivision and damage stability requirements apply, precautions are to be taken to prevent progressive flooding between compartments resulting from damage to piping systems. For this purpose, piping systems are to be located inboard of the assumed extent of damage applicable to the requirements of the Flag Administration.

1.2.2 Where it is not practicable to locate piping systems as required by *Pt 5, Ch 11, 1.2 Prevention of progressive flooding in damage condition 1.2.1*, the following precautions are to be taken:

(a) Bilge suction pipes are to be provided with non-return valves of approved type.
(b) Other piping systems are to be provided with shut-off valves capable of being operated from positions accessible in the damage condition, or from above the bulkhead deck.

These valves are to be located in the compartment containing the open end or in a suitable position such that the compartment may be isolated in the event of damage to the piping system.

1.2.3 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

1.3 Plans and particulars

1.3.1 The following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of a novel or special character affecting classification:

(a) Arrangements of air pipes and closing devices for all tanks and enclosed spaces.
(b) Sounding arrangements for all tanks, enclosed spaces and cargo holds.
(c) Arrangements of level alarms fitted in tanks, cargo holds, machinery spaces, pump rooms and any other spaces.
(d) Arrangements of any cross flooding or healing tank systems.
(e) Bilge drainage arrangements for all compartments which are to include details of location, number and capacity of pumping units on bilge service.
(f) Ballast filling and drainage arrangements.
(g) Fuel oil filling, transfer, relief and spill/drainage arrangements.
(h) Tank overflow arrangements.
(i) Arrangements for flooding holds together with blanking arrangements for bilge and ballast piping systems for bulk carriers having floodable holds intended for the carriage of dangerous goods.
(j) Bilge systems for bulk carriers where the cargo holds are intended for the carriage of dangerous goods.
(k) Details verifying compliance with the sizing of air pipes required by *Pt 5, Ch 11, 10.8 Size of air pipes*.
(l) Arrangements of fuel oil piping in connection with oil burning installations and oil fired galleys.
(m) Arrangements of fuel oil burning units for boilers and thermal fluid heaters.
(n) Arrangement of boiler feed system.
(o) Arrangements of thermal fluid circulation systems.
(p) Arrangement of compressed air systems for main and auxiliary services.
(q) Arrangement of lubricating oil systems.
(r) Arrangements of flammable liquids used for control and heating systems
(s) Arrangements of power transmission systems for services essential for safety or for the operation of the ship on the inland waterway.
(t) Arrangements of cooling water systems for main and auxiliary services.
(u) Fuel oil tanks and lubricating and hydraulic oil tanks with a capacity of 500 litres or more, not forming part of the ship's structure.
(v) Arrangements and dimensions of all steam pipes, with details of flanges, bolts and weld attachments, and particulars of the material of pipes, flanges, bolts and electrodes.
(w) Arrangements and details of box coolers for main and auxiliary services.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

2.1.2 Where applicable, the materials are to comply with the relevant requirements of *Pt 5, Ch 10 Piping Design Requirements*.

2.1.3 Materials sensitive to heat, such as aluminium, lead or plastics, are not to be used in systems essential to the safe operation of the ship, or for containing combustible liquids or water where leakage or failure could result in fire or in the flooding of watertight compartments, *see Pt 5, Ch 10 Piping Design Requirements* for plastic pipes.

2.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The proposed use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations where the insulation material is likely to suffer from mechanical damage suitable protection is to be provided.

2.2 Pipe wall thicknesses

2.2.1 The minimum nominal wall thickness of steel, copper, copper alloy and stainless steel pipes is to be in accordance with *Pt 5, Ch 10 Piping Design Requirements*.

2.2.2 Special consideration will be given to the wall thicknesses of pipes made of materials other than mentioned in *Pt 5, Ch 11, 2.2 Pipe wall thicknesses 2.2.1*.

2.3 Valves - Installation and control

2.3.1 Valves and cocks are to be fitted in places where they are at all times readily accessible, unless otherwise specifically mentioned in the Rules. Valves in cargo oil and ballast systems may be fitted inside tanks, subject to *Pt 5, Ch 11, 2.3 Valves - Installation and control 2.3.2*.

2.3.2 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism. For shipside valves and valves on the collision bulkhead, the means for local manual operation are to be permanently attached. For submerged valves in cargo oil and ballast systems, as permitted by *Pt 5, Ch 11, 2.3 Valves - Installation and control 2.3.1*, local manual operation may be by extended spindle or a portable hand pump. Where manual operation is by hand pump, the control lines to each submerged valve are to incorporate quick coupling connections, as close to the valve actuator as practicable, to allow easy connection of the hand pump. Not less than two hand pumps are to be provided.

2.3.3 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

2.3.4 For general requirements of valves, *see Pt 5, Ch 10, 6 Valves*.

2.3.5 Remote controls of valves on passenger ships situated above the bulkhead deck are to be clearly indicated.

2.4 Attachment of valves to watertight plating

2.4.1 Valve chests, cocks, pipes or other fittings attached directly to the plating of tanks and to bulkheads, which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead pieces may be welded to the plating.

2.4.2 For requirements relating to valves on the collision bulkhead, *see Pt 5, Ch 11, 3.5 Fore and after peaks 3.5.3*.

2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.5.1 All water inlet and overboard discharge pipes are to be fitted with valves or cocks secured directly to the shell plating, or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads, or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

2.5.2 Valves for ship-side applications are to be installed such that the section of piping immediately inboard of the valve can be removed without affecting the watertight integrity of the hull.

2.5.3 Distance pieces of short, rigid construction, and made of approved material, may be fitted between the valves and shell plating. The thickness of such pipes is to be not less than:

(a) Shell thickness for pipes smaller or equal to NB 50.
(b) Shell thickness plus 2 mm for pipes greater than NB 50.

In addition to the above, the following conditions are to be met:

- Distance pieces are to be efficiently protected against corrosion.
- Distance pieces of steel may be welded to the shell plating.
- Details of the welded connections and of fabricated steel water boxes are to be submitted.

2.5.4 Gratings are to be fitted at all openings in the ship's side for inlet valves and inlet water boxes. The net area through the gratings is to be not less than twice that of the valves connected to the inlets.

2.5.5 Water inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions, and so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. The valve spindles are to extend above the lower platform.

2.5.6 Ship-side valves and fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

2.5.7 Valves, cocks and distance pieces, intended for installation on the ship's side below the load waterline, are to be tested by hydraulic pressure to not less than 5 bar.

2.6 Piping systems - Installation

2.6.1 Bilge, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints, except as mentioned in *Pt 5, Ch 11, 7.8 Bilge pipes in way of deep tanks*, and are to be efficiently secured in position to prevent chafing or lateral movement. For joints in fuel oil piping systems, *see Pt 5, Ch 12, 4.4 Pipes conveying oil*.

2.7 Provision for expansion

2.7.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.7.2 Where expansion pieces are fitted, they are to be of an approved type and are to be protected against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

2.7.3 Expansion pieces of an approved type incorporating special quality oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in water inlet lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements. Proposals to use such fittings in water lines for other services will be specially considered when plans of the pumping systems are submitted for approval.

2.7.4 For requirements relating to flexible hoses, *see Pt 5, Ch 10, 7 Flexible hoses*.

2.8 Miscellaneous requirements

2.8.1 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage, are to be efficiently protected.

2.8.2 So far as is practicable, pipelines, including exhaust pipes from engines, are not to be led in the vicinity of switchboards or other electrical appliances. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary. Short sounding pipes to tanks are not to terminate near electrical appliances, *see Pt 5, Ch 11, 10.12 Short sounding pipes 10.12.3*.

2.9 Testing after installation

2.9.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by *Pt 5, Ch 11, 1.2 Prevention of progressive flooding in damage condition 1.2.1*, together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

2.10 *Cross-reference*

2.10.1 For guidance on metal pipes for water services, *see Pt 5, Ch 10, 11 Guidance notes on metal pipes for water services*.

■ *Section 3* Drainage of compartments, other than machinery spaces

3.1 General

3.1.1 All ships are to be provided with an efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least

one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.1.2 In passenger ships, the pumping plant is to be capable of draining any watertight compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

3.1.3 In the case of dry compartments, the suctions required by *Pt 5, Ch 11, 3.1 General 3.1.1* are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

3.1.4 Void spaces which are permanently sealed need not be connected to the bilge system, *see also Pt 5, Ch 10, 2.2 Wrought steel pipes and bends 2.2.6*.

3.1.5 For drainage arrangements of non-self-propelled ships, *see Pt 5, Ch 11, 9 Drainage arrangements for ships not fitted with propelling machinery*.

3.1.6 For additional drainage arrangements on ferries and Roll on-Roll off ships, *see Pt 4, Ch 2 Ferries and Roll on-Roll off Ships*.

3.2 Cargo holds

3.2.1 In ships having only one hold, and this being over 30 m in length, bilge suctions are to be fitted in suitable positions in the fore and after sections of the hold.

3.2.2 In ships having flat bottoms with a breadth exceeding 5 m, bilge suctions are to be fitted in the wings.

3.2.3 Where close ceilings or continuous gusset plates are fitted over the bilges, arrangements are to be made whereby water in a hold compartment may find its way to the suction pipes.

3.2.4 In ships fitted with double bottoms, suitably located bilge wells are to be provided.

3.2.5 For cargo holds having non-weathertight hatch covers or where hatch covers have been omitted, drainage arrangements are to take into account the effects of additional water ingress into the hold(s). Such ships shall meet the requirements of *Pt 5, Ch 11, 3.2 Cargo holds 3.2.6*. *See Pt 5, Ch 11, 6.3 Capacity of pumps 6.3.2* for required bilge capacities.

3.2.6 High level bilge alarms are to be provided in cargo holds.

3.2.7 One of the bilge pumps dealing with the hold should be located in such a way that it will not be affected by a fire or other casualty to the space containing the other pump or the space containing the main source of power. This requirement is not applicable for pumps situated aft and forward in the cargo hold.

3.2.8 The above bilge pump should be supplied from a source of power other than the main source.

3.2.9 The bilge pumping system, including the piping system, should incorporate sufficient redundancy features so that the system will be fully operational and capable of dewatering the hold space(s) at the required capacity in the event of failure of one system component.

3.2.10 Drainage arrangements of cargo holds intended for the carriage of flammable or toxic liquids are to be independent of the bilge system(s) in the machinery space(s) and such ships shall meet the requirements of *Pt 5, Ch 11, 3.2 Cargo holds 3.2.11*.

3.2.11 Arrangements for the carriage of dangerous goods are to be in compliance with (Inter)National requirements and acceptable to the relevant Administration.

3.2.12 Drainage arrangements of cargo holds in double hull ships may be achieved by the installation of fixed submersible pumps fitted in the cargo hold(s) as per *Pt 5, Ch 11, 6.6 Submersible bilge pump arrangements*, with a capacity as per *Pt 5, Ch 11, 6.3 Capacity of pumps*and with d_m calculated as a branch bilge suction in compliance with *Pt 5, Ch 11, 5.2 Branch bilge suctions to cargo and machinery spaces 5.2.1*. Not less than two pumps are to be fitted crosswise in the cargo hold, i.e. one pump aft SB and one pump forward PS, or the other way around.

3.2.13 The discharge of the bilge pumps is preferably led directly overboard but may be led through the machinery space if the pipe is seamless and the circumferential welds are butt welds of the full penetration type and no other connections will be fitted in way of the machinery space. Flange connections in the piping are only permitted at the hull connection.

3.2.14 The fixed submersible pumps are to be accessible under all conditions of normal service.

3.2.15 The prime mover of the submersible pumps is to be of the intrinsically safe type when carrying flammable cargoes.

3.2.16 An additional emergency means of pumping is to be provided which may be a portable submersible self-priming pump with a capacity of not less than that required by *Pt 5, Ch 11, 3.2 Cargo holds 3.2.12*. If the required capacity is such that the

portability of the pump is no longer practicable, consideration should be given to divide the required capacity equally over two portable pumps. For storage of the portable pump(s), *see Pt 5, Ch 11, 4.2 Submersible pump drainage 4.2.3*.

3.2.17 Alternatively, drainage arrangements of the hold by means of two ejectors situated in the hold driven by pumps in the engine room(s) will be specially considered.

3.2.18 For single hull ships, the independent bilge system is to comply with the regular requirements as applicable for a cargo hold. Alternatively, a drainage arrangement as per *Pt 5, Ch 11, 3.2 Cargo holds 3.2.17* may be installed.

3.3 Flooding of holds

3.3.1 Flooding of the hold may be provided with a (dedicated) pump situated in the engine room(s).

3.3.2 During the carriage of dangerous goods, the connection with the hold is to be blinded off.

3.3.3 The Owners shall be informed that the stability of the vessel with a flooded hold shall be maintained under all conditions of service.

3.4 Tanks

3.4.1 All tanks (including double bottom tanks), whether used for water ballast, fuel oil or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

3.4.2 In general, the drainage arrangements are to be in accordance with *Pt 5, Ch 11, 3.1 General*. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

3.4.3 The pumping arrangements for tanks that are intended to carry cargo oil having a flash point of 55°C or above, are also to comply with the requirements of Chapter 12, *Pt 5, Ch 12, 2 Fuel oil - General requirements*, *Pt 5, Ch 12, 3 Fuel oil burning arrangements* and *Pt 5, Ch 12, 4 Fuel oil pumps, pipes, fittings, tanks, etc.*, so far as they are applicable.

3.5 Fore and after peaks

3.5.1 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

3.5.2 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions. Drainage of the after peak, for ships, other than passenger ships, may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

3.5.3 Except as permitted by *Pt 5, Ch 11, 3.5 Fore and after peaks 3.5.4*, the collision bulkhead in passenger ships is not to be pierced below the bulkhead deck by more than one pipe for dealing with the contents of the fore peak. The pipe is to be provided with a screw-down valve capable of being operated from an accessible position above the bulkhead deck, the chest being secured to the bulkhead inside the fore peak. An indicator is to be provided to show whether the valve is open or closed.

3.5.4 Where the forepeak in a passenger ship is divided into two compartments, the collision bulkhead may be pierced below the bulkhead deck by two pipes (i.e. one for each compartment) provided there is no practicable alternative to the fitting of a second pipe. Each pipe is to be provided with a screw-down valve, fitted and controlled as in *Pt 5, Ch 11, 3.5 Fore and after peaks 3.5.3*.

3.5.5 In ships other than passenger ships, pipes piercing the collision bulkhead are to be fitted with suitable valves operable from above the freeboard deck and the valve chests are to be secured to the bulkhead inside the forepeak. The valve may be fitted on the after side of the collision bulkhead, without remote control, provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space.

3.6 Spaces above fore peaks, after peaks and machinery spaces

3.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump bilge suctions. The chain locker is not to be drained into the fore peak.

3.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

3.6.3 Subject to special approval of any applicable subdivision requirements, the compartments referred to in 3.6.2 may be drained by scuppers of not less than 38 mm bore, discharging to the machinery space and fitted with selfclosing cocks situated in well lighted and visible positions.

3.6.4 Accommodation spaces which overhang the machinery space, may also be drained as in *Pt 5, Ch 11, 3.6 Spaces above fore peaks, after peaks and machinery spaces 3.6.3*.

3.7 Maintenance of integrity of bulkheads

3.7.1 The intactness of the machinery space bulkheads, required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to the machinery space from adjacent compartments which are situated below the bulkhead deck.

3.7.2 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

■ *Section 4*
Bilge drainage of machinery spaces

4.1 General

4.1.1 The bilge drainage arrangements in the machinery space are to comply with*Pt 5, Ch 11, 3.1 General*, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions may be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e. a suction led direct to an independent power pump. An example of the necessary arrangements is detailed in *Pt 5, Ch 11, 4.1 General 4.1.3*.

4.1.2 In passenger ships, the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

4.1.3 In ships in which the propelling machinery is situated at the after end of the ship, it will generally be necessary for bilge suctions to be fitted in the forward wings as well as in the after end of the machinery space, but each case will be dealt with according to the size and structural arrangements of the compartment.

4.2 Submersible pump drainage

4.2.1 For ships other than passenger ships where a bilge main is not fitted, the branch bilge suction referred to in *Pt 5, Ch 11, 4.1 General 4.1.1* and *Pt 5, Ch 11, 4.1 General 4.1.3* may be replaced by a suction from fixed installed submersible pumps in accordance with 6.6. The second bilge suction is to be either a second fixed installed submersible bilge pump or a direct bilge suction as detailed in *Pt 5, Ch 11, 5.3 Direct bilge suctions*. The capacity of each pump is to be in accordance with *Pt 5, Ch 11, 6.3 Capacity of pumps* with d_m calculated as the main bilge in accordance with *Pt 5, Ch 11, 5.1 Main bilge line 5.1.1*.

4.2.2 An emergency means of pumping out the compartment is to be provided where fixed submersible pumps will be fitted. The emergency bilge pumping arrangements may be provided by a portable submersible self-priming pump of a capacity not less than that required by *Pt 5, Ch 11, 6.3 Capacity of pumps*.

4.2.3 The pump referred to in *Pt 5, Ch 11, 4.2 Submersible pump drainage 4.2.2* together with its suction and delivery hoses is to be stored in a secure and safe locker marked ‘For emergency use only’, accessible from open deck and clear of the machinery space(s). The pump is to be available for immediate use. If the pump is electrically driven, it is to be supplied from the emergency switchboard.

4.3 Branch bilge suction arrangements connected to non-isolated bilge main

4.3.1 For ships other than passenger ships where the bilge main is not separated as per *Pt 5, Ch 11, 7.2 Isolation of bilge system 7.2.1*, the branch bilge suctions referred to in *Pt 5, Ch 11, 4.1 General 4.1.1* and *Pt 5, Ch 11, 4.1 General 4.1.3* may be connected to the common suction pipe between the two bilge pumps, provided one automatic non-return valve is fitted in each branch bilge suction in addition to the screw-down non-return valve required by *Pt 5, Ch 11, 7.1 Prevention of communication between compartments 7.1.1*.

Section 5
Sizes of bilge suction pipes

5.1 Main bilge line

5.1.1 The diameter, d_m, of the main bilge line is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1,5\sqrt{L(B+D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm

L = Rule length of ship as defined in *Pt 3, Ch 1, 6.1 Principal particulars*, in metres

B = Greatest moulded breadth of ship, in metres

D = moulded depth of bulkhead deck, in metres.

5.2 Branch bilge suctions to cargo and machinery spaces

5.2.1 The diameter, d_b, of branch bilge line suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 40 mm:

$$d_b = 2,0\sqrt{C(B+D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm

C = length of compartment, in metres,

B and D are as defined in *Pt 5, Ch 11, 5.1 Main bilge line 5.1.1*.

5.3 Direct bilge suctions

5.3.1 The direct bilge suction in the machinery space required by *Pt 5, Ch 11, 4.1 General 4.1.1* and referred to in *Pt 5, Ch 11, 4.2 Submersible pump drainage 4.2.1*. and *Pt 5, Ch 11, 5.5 Separate machinery spaces 5.5.2* is to be led to the largest independent power pump, and the arrangements are to be such that the direct suction can be used independently of the main bilge suctions.

5.3.2 The size of the direct bilge suction required by *Pt 5, Ch 11, 4.1 General 4.1.1* is to be not less than that determined by *Pt 5, Ch 11, 5.1 Main bilge line 5.1.1* or *Pt 5, Ch 11, 5.4 Main bilge line – Tankers and dry cargo ships having machinery spaces with their own bilge arrangements 5.4.1*, as applicable when connected to a power pump, and by *Pt 5, Ch 11, 5.2 Branch bilge suctions to cargo and machinery spaces 5.2.1* when connected to a hand pump in case of ships having engines not exceeding 220 kW.

5.4 Main bilge line – Tankers and dry cargo ships having machinery spaces with their own bilge arrangements

5.4.1 In tankers and ships, where the engine room pumps do not deal with bilge drainage outside the machinery space, the diameter of the main bilge is to be not less than that required by the following formula, to the nearest 5 mm, but in no case is the diameter to exceed that required for the main bilge suction as per *Pt 5, Ch 11, 5.1 Main bilge line 5.1.1*:

$$d_m = 3,1\sqrt{C(B+D)} + 25 \text{ mm}$$

where

C, B and D = are as defined in *Pt 5, Ch 11, 5.1 Main bilge line 5.1.1* and *Pt 5, Ch 11, 5.2 Branch bilge suctions to cargo and machinery spaces 5.2.1*.

5.5 Separate machinery spaces

5.5.1 The number and position of the branch bilge suctions in auxiliary engine rooms are to be the same as for cargo holds, *see Pt 5, Ch 11, 3.2 Cargo holds*.

5.5.2 In addition to the branch bilge suctions, required by *Pt 5, Ch 11, 5.5 Separate machinery spaces 5.5.1*, at least one independent power pump direct bilge suction is to be fitted in each compartment. Similar provision is to be made in separate motor rooms of electrically propelled ships.

5.5.3 In ships other than passenger ships where a bilge main is not fitted and the auxiliary machinery space is served by fixed installed submersible pumps in accordance with *Pt 5, Ch 11, 6.6 Submersible bilge pump arrangements*, an additional emergency means of pumping out the compartment is to be provided, *see Pt 5, Ch 11, 4.2 Submersible pump drainage 4.2.2* and *Pt 5, Ch 11, 4.2 Submersible pump drainage 4.2.3*.

5.5.4 In ships other than passenger ships, branch bilge suctions may be arranged as per *Pt 5, Ch 11, 4.3 Branch bilge suction arrangements connected to non-isolated bilge main*.

5.5.5 In passenger ships, each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more suctions are provided, there is to be at least one suction at each side of the space.

5.5.6 For the number of bilge pumps to be installed in separate machinery spaces, *see Pt 5, Ch 11, 6.1 Number of pumps 6.1.2*.

5.6 Distribution chest branch pipes

5.6.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

■ *Section 6*
Pumps on bilge service and their connections

6.1 Number of pumps

6.1.1 In ships, other than passenger ships, with engines up to 220 kW, at least one power bilge pump is to be provided which may be worked from the main engine. In addition, hand pump suctions are to be fitted. In ships with engines exceeding 220 kW, at least two power bilge pumps are to be provided in the machinery space, one of which may be worked from the main engines and the other is to be independently driven.

6.1.2 For ships, other than passenger ships having separate machinery spaces, not connected to a common bilge system and with installed auxiliary engines up to 220 kW, at least one power bilge pump is to be provided which may be worked from the auxiliary engine. In addition, hand pump suctions are to be fitted. For installed auxiliary engines exceeding 220 kW, at least two power bilge pumps are to be provided in the machinery space, one of which may be worked from the auxiliary engines and the other is to be independently driven.

6.1.3 In ships other than passenger ships, a bilge ejector in combination with a high pressure overboard water pump may be accepted as a substitute for an independent bilge pump as required by *Pt 5, Ch 11, 6.1 Number of pumps 6.1.1*.

6.1.4 For small passenger ships, additional independent power bilge pumps may be required, depending on the size of the ship and the proposed service.

6.1.5 For passenger ships with a Rule length exceeding 80 m, at least three power bilge pumps are to be provided, one of which may be operated from the main engines.

6.1.6 For location of pumps on passenger ships, *see Pt 5, Ch 11, 8.1 Location of bilge pumps and bilge main*.

6.2 General service pumps

6.2.1 The bilge pumps required by *Pt 5, Ch 11, 6.1 Number of pumps*, may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required.

6.2.2 Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that for ships other than passenger ships they are not used for pumping oil and that, if they are subject to occasional duty for the transfer or pumping of fuel oil suitable change-over arrangements are fitted to preclude the admission of oil into the fire main.

6.3 Capacity of pumps

6.3.1 The capacity of each bilge pump is to be not less than required by the following formula:

$$Q = \frac{5,75}{10^3} d_{m}^{2}$$

where

Q = capacity, in m^3/h

d_m = Rule internal diameter of main bilge line, in mm, as per *Pt 5, Ch 11, 3.2 Cargo holds 3.2.12*, *Pt 5, Ch 11, 5.1 Main bilge line 5.1.1* or *Pt 5, Ch 11, 5.4 Main bilge line – Tankers and dry cargo ships having machinery spaces with their own bilge arrangements 5.4.1* as applicable.

6.3.2 For open hatch dry cargo vessels, the capacity of each bilge pump unit, based on heavy rainfall, should be not less than required by the following formula:

$$Q = \frac{q C_h B_h}{1600} \text{ m}^3/\text{h}$$

where

Q = rainfall mm/h, as applicable for the geographical area in which the ship will operate with a minimum of 25 mm/h but not required to exceed 100 mm/h

C_h = length of the hold, in metres

B_h = breadth of the hold, in metres

The greater capacity as calculated by *Pt 5, Ch 11, 6.3 Capacity of pumps 6.3.1* or *Pt 5, Ch 11, 6.3 Capacity of pumps 6.3.2* will be applicable.

6.3.3 In ships other than passenger ships and ships not provided with submersible bilge pumps, where one bilge pump is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other pump. In general, this deficiency is to be limited to 30 per cent.

6.4 Self-priming pumps

6.4.1 All power pumps which are essential for bilge services are to be of the self-priming type.

6.5 Pump connections

6.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

6.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

6.6 Submersible bilge pump arrangements

6.6.1 Arrangements are to be such that at least two automatic non-return devices are to be fitted between the overboard discharge and the watertight space being served by the pump.

6.6.2 One of these devices is to be fitted at or near the shell as high as practicable but in any case well above the loaded waterline, and the other one may be situated in the pipe work to the pump.

Section 7
Pipe systems and their fittings

7.1 Prevention of communication between compartments

7.1.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the waterway or with tanks. For this purpose, screw-down nonreturn valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to the main bilge line.

7.2 Isolation of bilge system

7.2.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from water inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

7.3 Machinery space suctions – Mud boxes

7.3.1 Suctions for bilge drainage in machinery spaces are so far as practicable to be led from easily accessible mud boxes with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes.

7.3.2 Where compliance with *Pt 5, Ch 11, 7.3 Machinery space suctions – Mud boxes 7.3.1* is not practicable, strum boxes as described in *Pt 5, Ch 11, 7.4 Hold and other compartment suctions – Strum boxes 7.4.1* are to be fitted to the bilge suctions in the machinery space.

7.4 Hold and other compartment suctions – Strum boxes

7.4.1 The open ends of bilge suctions in holds and other compartments outside machinery spaces such as cofferdams and tanks other than those permanently arranged for the carriage of fresh water, water ballast, fuel oil or liquid cargo and for which other efficient means of pumping are provided are to be enclosed in strum boxes. The strum boxes are to be provided with perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

7.5 Tail pipes

7.5.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge is to be adequate to allow a full flow of water and to facilitate cleaning.

7.6 Location of fittings

7.6.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space platforms. Where this is not practicable, they may be situated just below the platform, provided readily removable traps or covers are fitted, and nameplates indicate the presence of these fittings.

7.7 Bilge pipes in way of double bottom tanks

7.7.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

7.7.2 Bilge pipes which have to pass through these tanks are to have a wall thickness in accordance with *Table 10.2.3 Minimum thickness for steel pipes*. The thickness of pipes made from material other than steel will be specially considered.

7.7.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

7.8 Bilge pipes in way of deep tanks

7.8.1 In way of deep tanks, bilge pipes should preferably be led through pipe tunnels but, where this is not done, the pipes are to be of steel, having a wall thickness in accordance with *Table 10.2.3 Minimum thickness for steel pipes*, with welded joints or heavy flanged joints. The number of joints is to be kept to a minimum.

7.8.2 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the special type approved for use in holds, *see Pt 5, Ch 11, 7.9 Hold bilge non-return valves 7.9.1*.

7.8.3 The pipes are to be tested, after installation, to a pressure not less than the maximum head to which the tanks can be subjected in service.

7.9 Hold bilge non-return valves

7.9.1 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

■ *Section 8*
Additional requirements for bilge drainage of passenger ships

8.1 Location of bilge pumps and bilge main

8.1.1 In passenger ships, the power bilge pumps required by *Pt 5, Ch 11, 6.1 Number of pumps 6.1.4* and *Pt 5, Ch 11, 6.1 Number of pumps 6.1.5*, are to be placed in separate watertight compartments which will not readily be flooded by the same damage. If the engines are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible.

8.1.2 In passenger ships, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the ship may be flooded. This requirement will be satisfied if:

- one of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck; or
- the pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required to withstand by Statutory Regulations at least one pump in an undamaged compartment will be available.

8.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the ship than , $\frac{B}{5}$ measured at right angles to the centreline at the level of the deepest load line,

where

B is the breadth of the ship.

8.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the line $\frac{B}{5}$, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the line $\frac{B}{5}$.

8.2 Prevention of communication between compartments in the event of damage

8.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $\frac{B}{5}$ or less than 0,5 m above the bottom, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

8.2.2 Open ended pipes and ventilation ducts are to be arranged such that in any condition of flooding water can not enter other watertight compartments:

(a) If several compartments are connected by means of open ended pipe lines or ventilation ducts they are to be arranged such that the open ends are situated above the maximum assumed damage condition.

(b) Pipelines are not required to comply with (a) above if the pipes/ ventilation ducts are provided with shut off valves capable of being operated from above the bulkhead deck.

(c) Pipelines having no open end are to be considered as not damaged if within the extend of damage and the distance from the bottom is more than 0,5 m.

8.3 Arrangement and control of bilge valves

8.3.1 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative in any compartment.

8.3.2 If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from above the bulkhead deck.

8.3.3 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case, only the valves and cocks necessary for the operation of the emergency system need to be capable of being operated from above the bulkhead deck.

8.3.4 All valves and cocks mentioned in *Pt 5, Ch 11, 8.3 Arrangement and control of bilge valves 8.3.2* and *Pt 5, Ch 11, 8.3 Arrangement and control of bilge valves 8.3.3* which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

■ *Section 9*
Drainage arrangements for ships not fitted with propelling machinery

9.1 Hand pumps

9.1.1 Where auxiliary power is not provided, hand pumps are to be fitted, in number and position, as may be required for the efficient drainage of the ship.

9.1.2 The pumps are to be capable of being worked from the upper deck or from positions above the load waterline which are at all times readily accessible. The suction lift is to be well within the capacity of the pump.

9.1.3 The pump capacity is to be based upon the diameter of the suction pipe as determined by the formula in *Pt 5, Ch 11, 5.2 Branch bilge suctions to cargo and machinery spaces 5.2.1*, or 40 mm, whichever is greater.

■ *Section 10*
Air and sounding pipes

10.1 Definitions

10.1.1 Reference to cargo oil in this Section is to be taken to mean cargo oil which has a flash point of 55°C or above (closed cup test).

10.2 Materials

10.2.1 Air and sounding pipes are to be made of steel or other approved material. For use of plastic pipes of approved type, *see Pt 5, Ch 10, 5 Plastic pipes*.

10.3 Nameplates

10.3.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

10.4 Air pipes

10.4.1 Air pipes are to be fitted to all tanks and other compartments (except the void space mentioned in *Pt 5, Ch 11, 3.1 General 3.1.4*). which are not fitted with alternative ventilation arrangements.

10.4.2 The air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

10.4.3 Air pipes are to be arranged to be self-draining under normal conditions of trim.

10.4.4 Air pipes passing through cargo holds are to be of substantial thickness and well protected against mechanical damage.

10.5 Termination of air pipes

10.5.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the waterway are to be led to above the deck. Air pipes to fuel oil and cargo oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open as follows;

(a) For height of air pipes above deck for fuel oil tanks on ships carrying dangerous goods or tankers, *see Pt 4, Ch 1, 12.5 Arrangements 12.5.3* and/or *Pt 4, Ch 4, 3.4 Miscellaneous 3.4.1*.
(b) For height of air pipes above deck, in general, *see Pt 3, Ch 11, 10 Air and sounding pipes*.

10.5.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

10.5.3 The open ends of air pipes to fuel oil and cargo oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled.

10.5.4 The location and arrangement of air pipes for fuel oil service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of outboard water or rainwater.

10.6 Gauze diaphragms

10.6.1 The open ends of air pipes to fuel oil and cargo oil tanks are to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

10.6.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see Pt 5, Ch 11, 10.8 Size of air pipes*.

10.7 Air pipe closing appliances

10.7.1 Air pipe closing devices are to be of a type acceptable to Lloyd's Register. If of an automatic opening type they are to be tested in accordance with a National or International Standard recognised by LR.

10.7.2 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

10.7.3 For closing requirements, *see also Pt 3, Ch 11, 10.3 Closing appliances*.

10.8 Size of air pipes

10.8.1 For every tank which can be filled by the ship’s pumps, the total cross-sectional area of the air pipes and the design of the air pipe closing devices is to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

10.8.2 In all cases, whether a tank is filled by ship’s pumps or other means, the total cross-sectional area of the air pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

10.8.3 Air pipes are to be not less than 40 mm bore. In the case of small gravity filled tanks smaller bore pipes may be accepted but in no case is the bore to be less than 25 mm.

10.9 Overflow sight glasses

10.9.1 Where overflow sight glasses are provided, they are to be in a vertically dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality, adequately protected from mechanical damage and well lit.

10.10 Sounding arrangements

10.10.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible (except the void spaces mentioned in *Pt 5, Ch 11, 3.1 General 3.1.4*). The soundings are to be taken as near the suction pipes as practicable.

10.10.2 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

10.10.3 Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyor.

10.10.4 Where gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, fuel oil or other flammable liquid, the glasses are to be of the flat type of heatresisting quality, adequately protected from mechanical damage, and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

10.11 Termination of sounding pipes

10.11.1 Except as permitted by *Pt 5, Ch 11, 10.12 Short sounding pipes* sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible, and in the case of fuel oil tanks, cargo oil tanks, lubricating oil tanks and tanks containing flammable oils, the sounding pipes are to be led to safe positions on the open deck.

10.11.2 For closing requirements, *see also Pt 3, Ch 11, 10 Air and sounding pipes*.

10.12 Short sounding pipes

10.12.1 In machinery spaces where it is not practicable to extend the sounding pipes as mentioned in *Pt 5, Ch 11, 10.11 Termination of sounding pipes*, short sounding pipes extending to well lighted readily accessible positions above the platform may be fitted to double bottom tanks. Any proposal to terminate in the machinery space, sounding pipes to tanks, other than double bottom tanks, will be the subject of special consideration.

10.12.2 Short sounding pipes to fuel oil, (flash point not less than 55°C), lubricating oil tanks and other flammable oil tanks (flash point not less than 55ºC) are to be fitted with cocks having parallel plugs with permanently attached handles, loaded such that, on being released, they automatically close the cocks. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned above, in order to ensure that the sounding pipe is not under a pressure of oil before opening-up the sounding cock. Provision is to be made to ensure that discharge of oil through this test cock does not present an ignition hazard. An additional small diameter self-closing test cock is not required for lubricating oil tanks.

10.12.3 As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

10.12.4 In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in a machinery space, and are in all cases to be fitted with self-closing cocks as described in *Pt 5, Ch 11, 10.12 Short sounding pipes 10.12.1*.

10.13 Elbow sounding pipes

10.13.1 In passenger ships, elbow sounding pipes are not permitted.

10.13.2 Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them directly to the tanks or compartments, and subject to any sub-division and damage stability requirements that may apply.

10.13.3 The elbows are to be of heavy construction and adequately supported.

10.14 Striking plates

10.14.1 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

10.14.2 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

10.15 Sizes of sounding pipes

10.15.1 Sounding pipes are to be not less than 32 mm bore.

10.16 *Cross-references*

10.16.1 For ventilating and gauging equipment for cargo tanks in oil and chemical tankers, *see Pt 5, Ch 13, 4 Cargo tanks for Type G tankers*and *Pt 5, Ch 13, 5 Cargo tank venting arrangements*.

For control engineering equipment, *see Pt 6, Ch 1 Control Engineering Systems*.

For requirements relating to scuppers and sanitary discharges, *see Pt 3, Ch 11 Closing Arrangements to Openings in Shell and Deck, Ventilators, Air Pipes, Sounding Pipes and Discharges*.

■ *Section 1* General requirements

1.1 General

1.1.1 In addition to the requirements detailed in this Chapter, the requirements of *Pt 5, Ch 11, 1 General requirements* and *Pt 5, Ch 11, 2 Construction and installation* are to be complied with, where applicable.

1.1.2 The requirements of *Pt 5, Ch 11, 3 Drainage of compartments, other than machinery spaces* are also to be complied with, so far as they are applicable, for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.3 The requirements of *Pt 5, Ch 12, 2 Fuel oil - General requirements* and *Pt 5, Ch 12, 4 Fuel oil pumps, pipes, fittings, tanks, etc.* are to be complied with, as far as they are applicable, for all flammable liquids.

■ *Section 2* Fuel oil - General requirements

2.1 Flash point

2.1.1 The flash point (closed cup test) is to be not less than 55°C unless specially approved.

2.1.2 Fuels with flash points lower than 55°C may be used in ships intended for service restricted to geographical limits where it can be ensured that the temperature of the machinery spaces will always be 10°C below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered. However, the flash point of the fuel is to be not less than 43°C unless specially approved.

2.1.3 Where it is proposed to use gaseous fuels for main or auxiliary engines in inland waterways ships, and permitted by the national or regional administration, the relevant requirements of the *Rules and Regulations for the Classification of Natural Gas Fuelled Ships* are to be complied with and full details of the proposed arrangements are to be submitted for special consideration.

2.2 Ventilation

2.2.1 The spaces in which the fuel oil burning appliances and the fuel oil settling and service tanks are fitted are to be well ventilated and easy of access.

2.3 Boiler and thermal oil heater insulation and air circulation

2.3.1 The boilers and thermal oil heaters are to be suitably lagged. The clearance spaces between the boilers or heaters and the sides of storage tanks in which fuel oil and cargo oil is carried, are to be adequate for the free circulation of the air necessary to keep the temperature of the stored oil sufficiently below its flash point.

2.4 Heating arrangements

2.4.1 Where steam is used for heating fuel oil, cargo oil or lubricating oil, in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil, *see Pt 5, Ch 13, 7.4 Heating circuits*.

2.4.2 Where hot water is used for heating, means are to be provided for detecting the presence of oil in the return lines from the heating coils.

2.4.3 For requirements of thermal oil systems as heating medium, *see Pt 5, Ch 12, 11 Thermal oil systems*and *Pt 5, Ch 13, 7 Cargo heating arrangements*.

2.4.4 The steam heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy, and after being fitted on board, are to be tested by hydraulic pressure in accordance with the requirements of *Pt 5, Ch 10, 8.2 Testing after assembly on board*.

2.4.5 Where electric heating elements are fitted, means are to be provided to ensure that all elements are submerged at all times when electric current is flowing and that their surface temperature cannot exceed 220°C.

2.4.6 For requirements of heating cargo tanks, *see Pt 5, Ch 13, 7 Cargo heating arrangements*.

2.5 Temperature indication

2.5.1 Tanks and heaters in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil.

2.5.2 Where thermometers or temperature sensing devices are not fitted in blind pockets, a warning notice, in raised letters, is to be affixed adjacent to the fittings stating 'Do not remove unless tank/heater is drained'.

2.5.3 Controls are to be fitted to limit oil temperatures in oil storage and service tanks and in oil heaters to the maximum approved operating temperature, *see Pt 6, Ch 1 Control Engineering Systems*.

2.6 Precautions against fire

2.6.1 Settling and daily service fuel oil tanks and fuel oil filters are not to be situated immediately above boilers or other highly heated surfaces. *See also Pt 5, Ch 1, 4.4 Fire protection*.

2.6.2 Fuel oil pipes are not to be installed above or near high temperature equipment. Fuel oil pipes should also be installed, and screened or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and, where provided, are to be of a type acceptable to Lloyd's Register (hereinafter referred to as LR). Pipes are to be led in well lighted and readily visible positions. *See also Pt 5, Ch 2, 8 Piping*.

2.6.3 Pumps, filters, strainers and heaters are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filters and strainers is to be such that they cannot be opened when under pressure and suitable means for pressure release are to be provided, with drain pipes led to a safe location.

2.6.4 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with *Pt 5, Ch 11, 10.12 Short sounding pipes*. For alternative sounding arrangements, *see Pt 5, Ch 11, 10.10 Sounding arrangements*.

2.6.5 So far as is practicable, the use of wood is to be avoided in the machinery spaces of ships burning fuel oil.

2.6.6 Drip trays are to be fitted under all fuel oil appliances which are required to be opened up frequently for cleaning or adjustment.

2.6.7 Oil-tight drip trays of ample size having suitable drainage arrangements should be provided at pipes, pumps, valves and other fittings where there is a possibility of leakage. Valves should be located in well lighted and readily visible positions. Drip trays will not be required where pumps, valves and other fittings are placed in special compartments either inside or outside the machinery space with approved overall drainage arrangements, *see Pt 5, Ch 12, 2.6 Precautions against fire 2.6.2*.

2.6.8 Where drainage arrangements are provided from collected leakages, they are to be led to a suitable oil drain tank not forming part of an overflow system.

2.6.9 Separate fuel oil tanks are to be placed in an oiltight spill tray of ample size having drainage arrangements leading to a drain tank of suitable size, *see Pt 5, Ch 12, 4.10 Separate fuel oil tanks*.

2.6.10 Where level switches are used below the tank top, they are to be contained in a steel enclosure or other enclosures which provide equivalent protection against fire.

2.7 Fuel oil contamination

2.7.1 The use of copper or zinc compounds in fuel oil distribution and utilisation piping is not permitted except for small diameter pipes in low pressure systems, *see Pt 5, Ch 12, 4.4 Pipes conveying oil 4.4.1*.

2.8 Tank and cofferdams

2.8.1 Tanks containing fuel oil/lubricating oil are to be separated from passenger, crew and baggage compartments by a gastight and watertight boundary or alternatively by a cofferdam.

2.8.2 A cofferdam between the passenger, crew and baggage compartments is mandatory when the common bulkhead is subject to a static liquid pressure under normal service conditions.

2.8.3 Any cofferdam adjacent to a fuel oil/lubricating oil tank is to be suitably ventilated and drained.

■ *Section 3*
Fuel oil burning arrangements

3.1 Oil burning units

3.1.1 Means are to be provided so that, in the event of flame failure, the fuel oil supply to the burner(s) is shut-off automatically, and an alarm is given, *see Pt 6, Ch 1, 3.3 Boilers and thermal fluid heaters 3.3.2*.

3.1.2 A warning notice is to be fitted in a prominent position at every oil burning unit local manual control station which specifies that burners operated with manual or local overrides in use are only to be ignited after sufficient purging of the furnace and of any additional precautions required when operating in this condition.

3.1.3 For thermal oil heater arrangements, *see also Pt 5, Ch 12, 11.4 Thermal oil heater arrangements*.

3.2 Fuel oil supply to main and auxiliary engines

3.2.1 Two or more filters are to be fitted in the fuel oil supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered fuel oil to the engines.

3.3 Burner arrangements

3.3.1 The burner arrangements are to be such that a burner cannot be withdrawn unless the fuel oil supply to that burner is shut-off, and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

3.4 Quick-closing valve

3.4.1 A quick-closing master valve is to be fitted to the oil supply to each thermal oil heater or boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls. A quick-closing master valve is not required to be fitted if the thermal oil heater has a dedicated quick-closing valve fitted to the fuel oil daily service tank to which it is connected providing the heater and tank are in close proximity (*see Pt 5, Ch 12, 4.6 Valves on tanks and their control arrangements*).

3.5 Spill arrangements

3.5.1 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.

■ Section 4 Fuel oil pumps, pipes, fittings, tanks, etc.

4.1 Control of pumps

4.1.1 The power supply to all independently driven fuel oil transfer and pressure pumps is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which they are situated, as well as from the compartment itself.

4.2 Relief valves on pumps

4.2.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves or approved equivalent means. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.2.2 Where centrifugal type pumps are fitted, pressure-relief valves will not be required, provided that pipes, valves and fittings are suitable for the greater of the design pressure or pump non-delivery pressure.

4.3 Pump connections

4.3.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.4 Pipes conveying oil

4.4.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of steel, having flanged or other approved joints suitable for a working pressure of not less than 7 bar. The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm bore or less, they may be of seamless copper or copper alloy, except those which pass through oil storage tanks. Oil pipes within the machinery spaces are to be fitted where they can be readily inspected and repaired.

4.4.2 Pipes conveying oil under pressure are to be of seamless steel or other approved material having flanged or welded joints suitable for a working pressure of not less than 16 bar, are to be placed in sight above the platform in well lighted and readily accessible parts of the machinery spaces. The number of flanged joints are to be kept to a minimum.

4.4.3 Where pipes convey heated oil under pressure, the flanges are to be machined, and the jointing material, which is to be impervious to oil heated to 150 °C, is to be the thinnest possible, so that the flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 14 bar or for the design pressure, whichever is the greater.

4.4.4 For requirements regarding bilge pipes in way of double bottom tanks and deep tanks, *see Pt 5, Ch 11, 7.7 Bilge pipes in way of double bottom tanks* and *Pt 5, Ch 11, 7.8 Bilge pipes in way of deep tanks*.

4.4.5 For requirements relating to flexible hoses, *see Pt 5, Ch 10, 7 Flexible hoses*.

4.4.6 Fuel oil tanks in the machinery space situated at Port side and Starboard side may be connected with a crossover. Where fitted, the arrangements are to comply with the requirements of *Pt 5, Ch 12, 4.4 Pipes conveying oil 4.4.7*.

4.4.7 The crossover is provided with valves of an approved type and ductile material, fitted in a visible and accessible position and secured to the relevant tanks.

4.4.8 The crossover pipe must have a diameter of not less than 3” (88,9 mm) and a wall thickness of not less than 8,8 mm and is to be suitably protected against mechanical damage. The pipe is to be manufactured from seamless steel or other approved material having welded joints of the full penetration type.

4.4.9 Connections on the crossover intended for fuel oil supply to the engines or any boiler may be fitted provided a quick closing valve as per *Pt 5, Ch 12, 4.6 Valves on tanks and their control arrangements 4.6.2* is installed at each connection.

4.4.10 Alternatively, when the valves for the crossover fitted to the tanks are quick closing valves, the following conditions are to be complied with;

- The wall thickness of the crossover pipe is to be not less than indicated in *Table 10.2.3 Minimum thickness for steel pipes*, last column.

- The crossover pipe is to be in compliance with *Pt 5, Ch 12, 4.4 Pipes conveying oil 4.4.2*.
- The individual connections to the engines and boilers are not required to comply with *Pt 5, Ch 12, 4.4 Pipes conveying oil 4.4.9*.
- Operating the quick closing valves of the crossover should not lead to shut-off of the fuel supply to main and auxiliary engines causing a dead ship situation.

4.5 Valves and cocks

4.5.1 Valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water.

4.5.2 All valves and cocks forming part of the fuel oil installation are to be capable of being controlled from readily accessible positions which, in the machinery spaces, are to be above the working platform. *See also Pt 5, Ch 11, 2.3 Valves - Installation and control*.

4.5.3 Every fuel oil suction pipe from a double bottom tank is to be fitted with a valve or cock.

4.6 Valves on tanks and their control arrangements

4.6.1 Every fuel oil suction pipe from a storage, settling and daily service tank and every fuel oil levelling pipe within the machinery spaces is to be fitted with a valve or cock secured to the tank.

4.6.2 The valves and cocks mentioned in *Pt 5, Ch 12, 4.6 Valves on tanks and their control arrangements 4.6.1* are to be capable of being closed locally and from positions outside the space in which the tank is located. The remote controls are to be accessible in the event of fire occurring in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.6.3 In the case of tanks of less than 500 litres capacity, consideration will be given to the omission of remote controls.

4.6.4 Where the filling pipes to oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in *Pt 5, Ch 12, 4.6 Valves on tanks and their control arrangements 4.6.2*.

4.7 Water drainage from settling tanks

4.7.1 Settling tanks are to be provided with means of draining water from the bottom of the tanks.

4.7.2 If settling tanks are not provided, the fuel oil bunkers or daily service tanks are to be fitted with water drains.

4.7.3 Open drains for removing water from oil tanks are to be fitted with valves or cocks of self-closing type, and suitable provision is to be made for collecting the oily discharge.

4.8 Separation of cargo oils from fuel oil

4.8.1 Pipes conveying vegetable oils, edible oils or similar cargo oils are not to be led through fuel oil tanks, nor are fuel oil pipes to be led through tanks containing these cargo oils. For requirements regarding provision of cofferdams between oil and water tanks, *see Pt 3, Ch 3 Structural Design*.

4.9 Fresh water piping

4.9.1 Pipes in connection with compartments used for storing fresh water are to be separate and distinct from any pipes which may be used for other liquids, and are not to be led through tanks which contain other liquids nor are pipes containing other liquids to be led through fresh water tanks.

4.9.2 Potable fresh water tanks are to be fitted into a cofferdam, *see Pt 3, Ch 7, 1.6 Protection of tanks carrying fuel oil, lubricating oil, vegetable or similar oils*.

4.10 Separate fuel oil tanks

4.10.1 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in *Table 12.4.1 Plate thickness of seperate fuel oil tanks*, and not less than 3 mm. The stiffeners are to be of approved dimensions.

Table 12.4.1 Plate thickness of seperate fuel oil tanks

Thickness of plate, in mm	Head from bottom of tank to top of overflow pipe, in metres				
	2,5	3,0	3,5	4,0	4,5
	Breadth of panel, in mm				
3	315	290	—	—	—
4	475	435	400	375	350
5	630	575	535	500	470
6	790	720	670	625	590
7	950	865	800	750	710
8	1105	1010	935	875	825

4.10.2 The dimension given in *Table 12.4.1 Plate thickness of seperate fuel oil tanks* for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, washplates or the boundary of the tank.

4.10.3 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

4.10.4 The dimension given in *Table 12.4.1 Plate thickness of seperate fuel oil tanks* for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, washplates or the boundary of the tank.

4.10.5 Valves are to be attached direct to the tank plating. These fittings are to be secured by studs screwed into heavy steel pads welded to the plating. Alternatively, a short rigid pipe stub, welded into the shell plating and provided with a flange, may be used.

4.10.6 Threaded connections below the oil level may be used up to and including NB 25, provided tapered threads will be used. Alternatively, threaded connections with parallel threads, intended for instrumentation connections, are to be provided with a collar and a facing around the hole in order to provide a joint face.

■ *Section 5* Steam piping systems

5.1 Provision for expansion

5.1.1 In all steam piping systems, provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.1.2 Where expansion pieces are used, particulars are to be submitted.

5.1.3 For installation requirements regarding expansion pieces, *see Pt 5, Ch 11, 2.7 Provision for expansion*.

5.2 Drainage

5.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any position of the steam piping system.

5.2.2 Arrangements are to be made for ready access to the drain valves or cocks.

5.3 Pipes in way of holds

5.3.1 In general, steam pipes are not to be led through spaces which may be used for cargo, but where it is impracticable to avoid this arrangement, plans are to be submitted for consideration. The pipes are to be efficiently secured and insulated, and well protected from mechanical damage. Pipe joints are to be as few as practicable and preferably butt welded.

5.4 Pipes in dangerous area of tankers

5.4.1 The surface temperature of the steam pipes fitted on deck or in the pump room of tankers is not to exceed 220°C.

5.5 Reduced pressure lines

5.5.1 Pipelines which are situated on the low pressure side of reducing valves, and which are not designed to withstand the full pressure at the source of supply, are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect the piping against excessive pressure.

■ *Section 6*
Boiler feed water systems

6.1 General

6.1.1 In view of the limited use of steam on ships for Inland Waterways, feed water systems will be considered in accordance with *Pt 5, Ch 14, 6 Boiler feed water, condensate and thermal fluid circulation systems* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) as far as they are applicable.

■ *Section 7*
Engine cooling water systems

7.1 Cooling water supply

7.1.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also the lubricating oil and fresh water coolers, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.2 Relief valves on main cooling water pumps

7.2.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

7.3 Water inlets

7.3.1 Not less than two water inlets are to be provided for the pumps supplying the cooling water system.

7.3.2 Cooling water pump inlets are to be low inlets.

7.4 Strainers

7.4.1 Where outboard water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

7.5 Box coolers

7.5.1 Box coolers with the top of the inlet chest less than 400 mm above the waterline shall not be dismounted when the ship is afloat. A legible name plate is to be fitted in a prominent position to that effect.

7.5.2 Box coolers with the top of the inlet chest exceeding 400 mm may be dismounted when the ship is afloat with permission of the skipper. A legible name plate is to be fitted in a prominent position to that effect.

7.5.3 Box cooler chests are to be provided with a suitable de-aeration pipe of extra heavy gauge with an approved shipside valve. The pipe is to be led to above the waterline.

7.6 *Cross-reference*

7.6.1 For guidance on metal pipes for water services, *see Pt 5, Ch 10, 11 Guidance notes on metal pipes for water services*.

■ *Section 8*
Lubricating oil systems

8.1 General

8.1.1 In addition to the requirements detailed in this Section, the requirements of Sections 2 and 4 are to be complied with in so far as they are applicable. In all cases, the following are to apply:

- *Pt 5, Ch 12, 2.6 Precautions against fire 2.6.1*, Precautions against fire.
- *Pt 5, Ch 12, 4.1 Control of pumps*, Control of pumps.
- *Pt 5, Ch 12, 4.2 Relief valves on pumps*, Relief valves on pumps.
- *Pt 5, Ch 12, 4.4 Pipes conveying oil*, Pipes conveying oil.
- *Pt 5, Ch 12, 4.10 Separate fuel oil tanks*, Separate fuel oil tanks.
- *Pt 5, Ch 12, 4.6 Valves on tanks and their control arrangements 4.6.1*, Valve or cock secured to the tank.

8.1.2 Satisfactory lubrication of the engines is to be ensured while starting and manouvring.

8.1.3 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

8.2 Alarms

8.2.1 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 37 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

8.3 Filters

8.3.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of oil to the engine.

8.4 Cleanliness of pipes and fittings

8.4.1 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

8.5 Lubricating oil contamination

8.5.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce contaminants or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may normally come into contact with the oil is not permitted.

8.5.2 The design and construction of engine and gear box piping arrangements are to prevent as far as practicable, contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform.

8.5.3 Where a lubricating oil filling pipe and cap are provided for engines or other machinery, provision is to be made for the topping up oil to safely pass through a suitable strainer. The caps are to be capable of being secured in the closed position.

Section 9
Hydraulic systems

9.1 General

9.1.1 The requirements of this Section are applicable to flammable oils employed under pressure in power transmission, control, actuating and heating systems.

9.1.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed in the systems defined in *Pt 5, Ch 12, 9.1 General 9.1.1* are to comply, where applicable, with the provisions of:

- *Pt 5, Ch 12, 2.6 Precautions against fire 2.6.1*, Precautions against fire.
- *Pt 5, Ch 12, 4.1 Control of pumps*, Control of pumps.
- *Pt 5, Ch 12, 4.2 Relief valves on pumps*, Relief valves on pumps.
- *Pt 5, Ch 12, 4.4 Pipes conveying oil*, Pipes conveying oil.
- *Pt 5, Ch 12, 4.10 Separate fuel oil tanks*, Separate fuel oil tanks.
- *Pt 5, Ch 12, 4.6 Valves on tanks and their control arrangements 4.6.1*, Valve or cock secured to the tank.

9.2 System arrangements

9.2.1 Hydraulic fluids are to be suitable for the intended purpose under all operating service conditions.

9.2.2 Materials used for all parts of hydraulic seals are to be compatible with the working fluid at the appropriate working temperature and pressure.

9.2.3 Provision is to be made for hand operation of the systems in an emergency, unless an acceptable alternative is available.

9.2.4 Where hydraulic securing arrangements are applied, the system is to be capable of being locked in the closed position, so that in the event of hydraulic system failure, the securing arrangements will remain locked.

9.2.5 Where pilot operated non-return valves are fitted to hydraulic cylinders for locking purposes, the valves are to be connected directly to the actuating cylinder(s) without intermediate pipes or hoses.

9.2.6 For requirements relating to hydraulic steering gear arrangements, *see Pt 5, Ch 15, 3 Construction and design*.

9.2.7 For requirements relating to hydraulic systems for liftable wheelhouses, *see Pt 5, Ch 18, 2 Pumping and piping* and *Pt 5, Ch 18, 3 Hydraulic cylinder*.

9.2.8 Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

Section 10
Low pressure compressed air systems

10.1 General

10.1.1 The requirements of this Section are applicable to low pressure (LP) compressed air systems intended for essential pneumatic control and instrumentation purposes.

10.2 Compressors

10.2.1 Air compressors are in general to comply with the requirements of *Pt 5, Ch 2, 9 Starting arrangements, air compressors and batteries*.

10.3 Air receivers

10.3.1 All air receivers are to comply with the requirements of *Pt 5, Ch 9 Pressure Vessels other than Boilers*, as applicable.

10.3.2 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

10.4 Distribution system

10.4.1 Pipelines that are situated on the low pressure side of reducing valves/stations and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and relief valves, having sufficient capacity to protect the piping against excessive pressure.

10.4.2 Low pressure compressed air distribution pipes led to the dangerous area of a tanker are to be provided with a spring-loaded non-return valve situated in the dangerous area directly after the bulkhead/deck penetration.

10.5 Pneumatic remote control valves

10.5.1 Where valves, which are required by the Rules to be capable of being closed from outside a machinery space, have pneumatic closing arrangements, a dedicated air receiver is to be fitted to supply compressed air to the valves. This air receiver is to be located outside the machinery space.

10.5.2 The air receiver is to be maintained fully charged from the main LP air system via a non-return valve located at the air receiver inlet which is to be locked in the open position.

10.5.3 In the case of passenger ships, a permanently attached hand-operated air compressor capable of charging the air receiver is to be provided in the space in which the air receiver is located.

10.5.4 The capacity of the air receiver is to be sufficient to operate all valves and any other essential supplies such as ventilation flaps without replenishment.

10.5.5 The pneumatic pilot pipes running through the machinery space to the relevant control mechanism of the valves are to be of steel.

10.6 Control arrangements

10.6.1 The control, alarm and monitoring systems are to comply with *Pt 6, Ch 1 Control Engineering Systems*.

■ *Section 11*
Thermal oil systems

11.1 General

11.1.1 The requirements of this Section are applicable to thermal oil systems heated by oil fired appliances intended for heating of cargo.

11.1.2 Exhaust gas heating arrangements and heating arrangements intended for own propulsion will be specially considered.

11.1.3 The arrangements for storage, distribution and utilisation of thermal oil under pressure are to comply with the requirements detailed in this Section. The requirements of *Pt 5, Ch 12, 1 General requirements*, *Pt 5, Ch 12, 2 Fuel oil - General requirements*, *Pt 5, Ch 12, 3 Fuel oil burning arrangements* and *Pt 5, Ch 12, 4 Fuel oil pumps, pipes, fittings, tanks, etc.* are to be complied with in so far as they are applicable. In all cases, the following are to apply:

- *Pt 5, Ch 12, 2.6 Precautions against fire 2.6.1*, Precautions against fire.
- *Pt 5, Ch 12, 4.1 Control of pumps*, Control of pumps.
- *Pt 5, Ch 12, 4.2 Relief valves on pumps*, Relief valves on pumps.
- *Pt 5, Ch 12, 4.4 Pipes conveying oil*, Pipes conveying oil.
- *Pt 5, Ch 12, 4.6 Valves on tanks and their control arrangements*, Valves on tanks and their control arrangements.

11.1.4 An approved type of thermal oil is to be used. The proposed thermal oil should be stated, giving flash point (>55°C), fire point, auto-ignition temperature and maximum operating temperature.

11.2 Piping

11.2.1 Joints in thermal oil systems are preferably to be of welded construction, where used the number of flanged joints is to be kept to a minimum.

11.2.2 Expansion joints of an approved type or bends are to be provided, where necessary, in the thermal oil pipe lines. Moreover, the thermal oil pipes are to be suitably supported and anchored.

11.2.3 All air release pipes in the system should be fitted with self-closing cocks and led to the expansion tank.

11.2.4 Suitable strainers should be fitted on the suction side of the circulating pumps to filter out any carbonised oil.

11.2.5 Copper and copper alloys are suspect able for catalytic action with thermal oil and should not be used.

11.2.6 Thermal oil pipes are not to be led through accommodation or service spaces. For service spaces situated inside the dangerous zone of tankers, *see Pt 5, Ch 13, 1.9 Bulkhead penetrations 1.9.4*.

11.2.7 Hydraulic tests and non-destructive examination on pipes and fittings are to comply with *Pt 5, Ch 10, 8 Hydraulic tests on pipes and fittings* and *Pt 5, Ch 14, 6 Non-Destructive Examination* respectively, as applicable.

11.2.8 Pipe penetrations through bulkheads or decks outside the cargo area are to be insulated.

11.3 Expansion tank arrangement

11.3.1 A positive pressure in the heating coils exceeding the external pressure is to be maintained under all conditions of service irrespective of the type of cargo to be carried. This can be achieved by means of an atmospheric expansion tank situated at sufficient height or by pressurising the expansion tank with an inert gas or compressed air. Arrangements for atmospheric expansion tanks are to comply with *Pt 5, Ch 12, 11.3 Expansion tank arrangement 11.3.3* and arrangements for pressurized expansion tanks are to comply with *Pt 5, Ch 12, 11.3 Expansion tank arrangement 11.3.6*.

11.3.2 For the minimum required pressure in the expansion tank or, alternatively, the minimum required height above the installation, *see Pt 5, Ch 13, 7.4 Heating circuits 7.4.8*.

11.3.3 Means of approved type are to be provided to ascertain the level in the thermal oil expansion tank.

11.3.4 The expansion/header tank is to be fitted with both high and low level alarms. At low level alarm, the circulation pump is to be stopped automatically and the thermal oil heater is to be shut down.

11.3.5 The vent pipe from the expansion tank is to be led to a safe position on the open deck.

11.3.6 For expansion tanks provided with an inert gas padding, it is to be guaranteed that sufficient inert gas will be available to maintain the pressure in the expansion vessel under all conditions of service.

11.3.7 For expansion tanks pressurised by compressed air, it is to be guaranteed that the temperature of the thermal oil in the expansion tank is not to exceed 50°C in order to avoid oxidation of the thermal oil.

11.3.8 The expansion vessel is to be provided with a pressure indication and alarm for the minimum pressure. At low pressure alarm, the circulation pump is to be stopped automatically and the thermal oil boiler is to be shut down.

11.3.9 A pressurised expansion vessel is to be protected against over pressure by a relief valve, the discharge of which is to be led to a safe position on the open deck.

11.3.10 As an alternative to the quick closing valve as per *Pt 5, Ch 12, 11.1 General 11.1.3*, a quick drainage arrangement can be installed as per *Pt 5, Ch 12, 11.3 Expansion tank arrangement 11.3.11* .

11.3.11 The expansion tank is to be provided with an quick opening valve remotely controlled from outside the space in which the expansion tank is situated.

11.3.12 The thermal oil dump tank shall have sufficient capacity to accumulate the contents of the expansion tank.

11.3.13 Actuating of the quick opening valve is to initiate stopping of the circulating pump(s) and shut down of the thermal oil heater.

11.4 Thermal oil heater arrangements

11.4.1 Alarms and safeguards are to be fitted in accordance with *Pt 6, Ch 1 Control Engineering Systems*.

11.4.2 A thermostatic control or cut-out actuated by the circulating thermal oil temperature, failure of the circulating thermal oil pumps and ‘flame out’, is to be incorporated in the oil fired thermal oil heater burner system.

11.4.3 The oil fired thermal oil heater is to be fitted with temperature sensors and alarms for fire detection.

11.4.4 For requirements of fuel oil burning arrangements, *see Pt 5, Ch 12, 3 Fuel oil burning arrangements*.

11.5 *Cross-references*

11.5.1 For air and sounding pipes and gauge glasses, *see Pt 5, Ch 11, 10 Air and sounding pipes*.

For separation of lubricating oil tanks from fuel tanks, *see Pt 3, Ch 3 Structural Design*. For thermal oil system requirements for oil and chemical tankers, *see Pt 5, Ch 13, 7 Cargo heating arrangements*.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are additional to those of *Pt 5, Ch 11 Ship Piping Systems* and are applicable to ships which are intended for the carriage of liquids in bulk, being self-propelled with machinery aft or non-propelled (barges) being towed, pushed or carried alongside another ship.

1.1.2 For the classification of dangerous liquids into Classes 2, 3, 6.1, 8 and 9, *see Pt 4, Ch 6, 1.3 Structural configuration*.

1.1.3 For the significance of tankers Types G, C and N and cargoes that may be carried, *see Pt 4, Ch 6, 1.4 Class notation* & *Pt 4, Ch 6, 1.5 List of Defined Cargoes*.

1.1.4 For applications and definitions, *see Pt 4, Ch 6, 1 General*

1.1.5 The requirements of this Chapter basically take into account the European provisions concerning the International Carriage of Dangerous Goods by Inland Waterways **ADN** which assume heavy traffic on relatively narrow waterways through heavily populated areas. ADN is an abbreviation from **A**ccord européen relative au transport international des merchandises **D**angereuses par voie de **N**avigation intérieure. *See also Pt 4, Ch 4, 1.2 International Regulations*.

1.1.6 Although the contents of this Chapter take the ADN Regulations into account, the issue of an ADN Certificate on behalf of the Relevant Authorities requires full compliance with their Regulations.

1.1.7 In addition to the requirements of this Chapter, attention is to be given to any National and International technical and operational requirements of countries where the ship is registered or operating, and which are outside the area of ADN legislation or classification as defined in these Rules.

1.1.8 In addition to the requirements of this Chapter the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, July 2022* (hereinafter referred to as the Rules for Ships for Liquefied Gases) are to complied with for Type G tankers as far as they are applicable.

1.2 Plans and particulars

1.2.1 In addition to the plans and particulars required in *Pt 5, Ch 11 Ship Piping Systems*, the following plans (in diagrammatic form) are to be submitted for consideration:

(a) Pumping arrangements at the fore and aft ends, and drainage of cofferdams and pump-rooms.
(b) General arrangements of cargo piping in tanks and on deck.
(c) For Type G tankers the maximum vapour pressure and minimum liquid temperature.

(d) General arrangements of cargo tank vents. The plan is to indicate the type and position of the vent outlets and distance from any superstructure, erection, air intake, etc.

(e) Arrangements of inert gas piping systems, together with full details of inert gas plant, if fitted. *See Pt 5, Ch 13, 9 Inert gas systems*.

(f) Details of alarms and safety arrangements required by *Pt 5, Ch 13, 1.6 Cargo pump-room*. *See also Pt 6, Ch 1, 2 Essential features for control, alarm and safety systems*.

(g) Pressure drop calculations, *see Pt 5, Ch 13, 5.5 Loading and unloading rates for Type C and Type N-closed tankers*.

(h) Cargo heating systems, *see Pt 5, Ch 13, 7 Cargo heating arrangements*.

(i) Water spray systems, *see Pt 5, Ch 13, 8.2 Water spray system*.

1.3 Materials

1.3.1 All materials used in the cargo pumping and piping systems and any other piping systems which may come into contact with the cargo are to be suitable for use with the intended cargoes.

1.3.2 Materials for cargo piping systems are to comply with the requirements of *Pt 5, Ch 10 Piping Design Requirements* as follows:

Class I or II systems for Type G Tankers depending on the service. *See also Pt 5, Ch 10, 9.3 Classes of pipe*.

Class II systems for Type C Tankers.

Class II for Type N Tankers carrying toxic or corrosive media.

Class III for all other Type N Tankers.

1.3.3 For cargoes which are highly corrosive, materials may be subject to a special consideration.

1.3.4 Where stainless steel is required or accepted as an alternative to mild steel, it is to be essentially an austenitic or duplex type and comply with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*. Alternative austenitic or duplex grades of stainless steel may be accepted provided they comply with National or Proprietary specifications and are suitable for the intended purpose.

1.3.5 For materials used on board Type G tankers carrying LPG, reference is made to *Pt 5, Ch 10, 9.4 Materials* for additional requirements.

1.3.6 Wood, aluminium alloy or plastic materials within the cargo area are in general not acceptable. However, consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.3.7 Vapour collecting or Vapour return pipe lines are to be suitably protected against corrosion.

1.3.8 A list of Defined Cargoes, intended to be carried on board, is to be established. Due account is to be given to the materials proposed. *See Pt 4, Ch 4, 1.3 Dangerous liquids*. *See Pt 4, Ch 5, 1.5 List of Defined Cargoes* for Type G tankers and *Pt 4, Ch 6, 1.5 List of Defined Cargoes* for Type C and N tankers.

1.3.9 For a list of dangerous goods, see the ADN, Table C, Part 3. Subject list of chemicals could be downloaded from: http://www.ccr-zkr.org. *See also Pt 4, Ch 6, 1.3 Structural configuration*.

1.3.10 All additional requirements for the particular substance as contained in Table C of Part 3 of the ADN are to be complied with by the particular tanker before a substance is allowed to be carried. This also includes any additional requirements contained in column 20 of Table C.

1.4 Design

1.4.1 All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected.

1.4.2 Piping subjected to pressure is to be of seamless or other approved type, and is to comply with the requirements of Chapter 10. Alternatively, longitudinally welded pipes could be accepted, provided the method of welding is acceptable and the weld will be Non-Destructive Examined in compliance with *Pt 5, Ch 14, 6 Non-Destructive Examination*.

1.4.3 Joints in cargo piping, outside the cargo tanks, are preferably to be of welded construction. Where used, the number of flanged joints is to be kept to a minimum and the types of flange attachments are to be in accordance with *Pt 5, Ch 10, 2 Carbon and low alloy steels*.

1.4.4 For Type C & N tankers, threaded pipe joints/ connections of an approved type are acceptable for NB 25 and smaller. A maximum diameter of 51 mm could be accepted for cargo oil only. *See also Pt 5, Ch 10, 2.10 Screwed fittings*.

1.4.5 For Type G tankers, screwed couplings could be accepted only for accessory lines and instrumentation lines with external diameters of 25 mm or less, provided the couplings are of an approved type.

1.4.6 Loading and discharge pipes, including stripping pipes are to be permanent pipes.

1.5 Cargo zone

1.5.1 For definition of cargo zone, *see Pt 4, Ch 4, 1.1 Application and definitions*.

1.5.2 Internal combustion engines, or any other equipment which could constitute a possible source of ignition, are not to be situated within the cargo zone, except in the case of Type N-open tankers not built in compliance with ADN requirements.

1.5.3 Any air intakes for machinery spaces and engines are to be so arranged that their openings are not less than 2 m outside the cargo zone.

1.5.4 For the requirements for earthing and bonding of pipework for the control of static electricity, *see Pt 6, Ch 2 Electrical Installations*.

1.5.5 Outlets of exhaust gas lines from engines are to be provided with a device to prevent the discharge of sparks such as spark arrestors. For all tankers, exhaust lines from engines are not to be led through the cargo zone, the distance between their outlets and the cargo zone shall be not less than 2 m and the exhaust gases should be blown out in a direction away from the ship.

1.5.6 For protection against the ingress of gases within accommodations and entrances (i.e. the relevant distances from openings and equipment in the cargo zone and openings and equipment outside the cargo zone) *see Pt 4, Ch 6, 3.3 Shell plating*.

1.6 Cargo pump-room

1.6.1 Cargo pump-rooms, if fitted, are to be totally enclosed and have no direct communication with machinery spaces. For bilge drainage arrangements in pump-rooms, *see Pt 5, Ch 13, 2.2 Drainage and/or ballasting of spaces within the cargo zone*.

1.6.2 For ships required to comply with the ADN Regulations, the cargo pump room is to be separated from the engine room or service space outside the cargo zone by a cofferdam, hold space containing cargo tanks or service space. Alternatively, the bulkhead between the machinery space/pump room or service space outside the cargo zone/pump room is to be provided with a fire insulation A-60 in accordance with *Regulation 3 - Definitions*. This requirement is not applicable for Type N - open tankers. Shaft penetrations for pumps as per *Pt 5, Ch 13, 2.2 Drainage and/or ballasting of spaces within the cargo zone 2.2.12* and *Pt 5, Ch 13, 3.2 Cargo pumps and compressors 3.2.5* are not acceptable for bulkheads having an A-60 insulation.

1.6.3 Pump-rooms are to be situated within the cargo zone and are to be provided with ready means of access from the deck.

1.6.4 Alarms and safety arrangements are to be provided as indicated in *Pt 5, Ch 13, 1.6 Cargo pump-room 1.6.5* and *Table 13.1.1 Alarms and safety arrangements*. These requirements are applicable to pump rooms where pumps for cargo, such as cargo pumps, stripping pumps, pumps for slop tanks, pumps for COW or similar pumps are provided and not for pump rooms intended solely for ballast transfer. *See also Pt 5, Ch 13, 1.6 Cargo pump-room 1.6.9*.

Table 13.1.1 Alarms and safety arrangements

Item	Alarm	Note
Temperature sensing of bulkhead shaft glands, bearings and pump casings	High *see* Note 1	Cargo, ballast and stripping pumps
Bilge level	High	–
Hydrocarbon concentration	High	> 10% LEL
Note The alarm signals shall trigger continuous visual and audible alarms at the position from which the cargo pumps will be controlled and in a permanently manned location		

1.6.5 A system for continuously monitoring the concentration of hydrocarbon gases and oxygen within the cargo pump room is to be fitted. Sampling points are to be located in positions such as in way of the bottom of the pump room and just below the main deck where potentially dangerous concentrations of hydrocarbon gases, or lack of oxygen, may be readily detected. This requirement is not applicable for Type N-open tankers.

1.6.6 Visual and audible alarms for the hydrocarbon concentration as per *Table 13.1.1 Alarms and safety arrangements* are to be fitted in the wheelhouse and pump room. At hydrocarbon alarm the gas discharge installation on Type G tankers is to be stopped. For all other tankers the loading or discharging installation is to be stopped.

1.6.7 An optic and acoustic alarm is to be provided in the wheelhouse and on deck indicating malfunctioning of the gas detection installation.

1.6.8 All cargo piping, including the stripping pipes for Type C and N tankers, except the N-open type, are to be provided with a valve secured to the bulkhead capable of being operated from an accessible position above the weather deck. See also 3.7. Control of the pump capacity is to be arranged also from this position.

1.6.9 Where items of equipment other than described in *Table 13.1.1 Alarms and safety arrangements* are located in the pump room and are driven by shafts passing through bulkheads, the potential risk of ignition of hydrocarbon gas is to be assessed and proposals for mitigation submitted to LR for consideration.

1.6.10 All cargo piping (suction and discharge side) for Type G tankers are to pass through the deck above the pump room the necessary control of valves in the pump room and control of the pump capacity is to be arranged from above the weather deck.

1.7 Cargo pump-room ventilation

1.7.1 For all tanker Types, the requirements of *Pt 5, Ch 13, 1.7 Cargo pump-room ventilation 1.7.2* are to be complied with. Natural ventilation is acceptable for Type N-open tankers.

1.7.2 Cargo pump-rooms and other enclosed spaces which contain cargo handling equipment, and to which regular access is required during cargo handling operations, are to be provided with permanent ventilation systems of the mechanical extraction type.

1.7.3 The ventilation system is to be capable of being operated from outside the compartment being ventilated, and the following notices are to be fixed near the entrance:

> “Before entering, pump room is to be tested for
> gas concentration and sufficient oxygen.”
>
> and
>
> “Doors and access openings are not to be opened
> without permission of the skipper.”
>
> and
>
> “In the event of alarm, pump room is to be left
> immediately”.

1.7.4 Before entering the space the ventilation system is to be in operation for at least 30 minutes.

1.7.5 The ventilation system is to start automatically in case of high alarm hydrocarbon concentration.

1.7.6 The ventilation system is to be capable of at least 30 air changes per hour, based on the gross volume of the pump-room.

1.7.7 The ventilation system is to be suitable for operation in a dangerous atmosphere.

1.7.8 The ventilation ducting is to be arranged to permit extraction from the vicinity of the pump-room bilges. Air intakes are to be so arranged in the upper part of the pumproom to minimise the possibility of recycling hazardous vapour from any ventilation discharge opening. Vent exits are to be arranged to discharge to a safe place on the open deck and comply with the requirements of *Pt 5, Ch 13, 1.7 Cargo pump-room ventilation 1.7.11*.

1.7.9 Renewable flame screens are to be provided in ventilation ducts.

1.7.10 Provision is to be made for closing the air intake and extraction ducts in case of fire. The means provided are to be capable of operation from the deck. This requirement is not applicable for Type N-open tankers.

1.7.11 Ventilation openings are to be arranged at a horizontal distance of not less than 6 m away from accommodation and service spaces outside the cargo zone. This requirement is not applicable for Type N-open tankers.

1.8 Non-sparking fans for hazardous areas

1.8.1 The air gap between impeller and housing of the fan is to be not less than 0,1 of the impeller shaft bearing diameter or 2 mm whichever is the larger, subject also to compliance with *Pt 5, Ch 13, 1.8 Non-sparking fans for hazardous areas 1.8.2.(e)*. Generally, however, the air gap need be no more than 13 mm.

1.8.2 The following combinations of materials are permissible for the impeller and the housing in way of the impeller:

(a) impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity;
(b) impellers and housings of non-ferrous metals;
(c) impellers and housings of austenitic stainless steel;
(d) impellers of aluminium alloys or magnesium alloys and a ferrous housing provided that a ring of suitable thickness of non-ferrous material is fitted in way of the impeller;
(e) any combination of ferrous impellers and housings with not less than 13 mm tip clearance;
(f) any combination of materials for the impeller and housing which are demonstrated as being sparkproof by appropriate rubbing tests.

1.8.3 The following combinations of materials for impellers and housings are not considered sparkproof and are not permitted:

(a) impellers of aluminium alloy or magnesium alloy and a ferrous housing irrespective of tip clearance;
(b) impellers of a ferrous material and housings made of an aluminium alloy, irrespective of tip clearance;
(c) any combination of ferrous impeller and housing with less than 13 mm tip clearance, other than permitted by *Pt 5, Ch 13, 1.8 Non-sparking fans for hazardous areas 1.8.2.(c)*.

1.8.4 Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials (i.e. materials having an electrical resistance between 5 x 10^4 ohms and 10^8 ohms), or special means are to be provided to avoid dangerous electrical charges on the surface of the material.

1.8.5 Evidence of satisfactory type testing of the complete fan, witnessed by a recognized Authority or by LR's Surveyors is to be provided.

1.8.6 Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation ducts to prevent the entry of objects into the fan housing.

1.8.7 The installation of the ventilation units on board is to be such as to ensure the safe bonding to the hull of the units themselves.

1.8.8 Non-sparking fans are not required for Type N-open tankers.

1.9 Bulkhead penetrations

1.9.1 Penetrations through the bulkhead between the machinery space and the pump room/cofferdam in the cargo area, or the bulkhead between the machinery space and the hold spaces containing cargo tanks may be provided for electrical cables, hydraulic lines and piping for measuring, control and alarm systems, provided that the penetrations are of an approved gastight type.

1.9.2 For ships required to comply with the ADN Regulations penetrations through a bulkhead with an 'A-60' fire protection insulation according to *Regulation 3 - Definitions*, shall have an equivalent fire protection. *See also Pt 5, Ch 13, 1.6 Cargo pump-room 1.6.2*.

1.9.3 Pipes may pass through the bulkhead between the machinery space and the pump room/cofferdam in the cargo area, provided that these pipes are connecting mechanical equipment between the machinery space and the pump room/cofferdam and do not have any openings within the pump room/cofferdam.

1.9.4 Pipes from the machinery space led to the open may pass through the pump-room/cofferdam/wing tank in the cargo area or a hold space containing the cargo tanks to the open, provided that, within the spaces mentioned above, they are:

- of substantial wall thickness
- without flanged joints or openings
- as short as practicable.

1.10 Service spaces in the cargo zone

1.10.1 Other enclosed spaces in the cargo zone not containing cargo handling equipment such as ballast pump rooms, etc. and to which regular access is required, are to be provided with permanent ventilation systems of the mechanical extraction type.

1.10.2 The ventilation system is to be capable of at least 20 air changes per hour, based on the gross volume of the service space.

1.10.3 The ventilation ducting is to be arranged to permit extraction from 50 mm above the bottom of the service space. For the arrangement of air intakes such as height and the required distances to tank hatches and safety valves, *see Pt 4, Ch 4, 3.2 Hold spaces, cargo tanks and service spaces 3.2.10*.

1.10.4 Mechanical ventilation fans are to be of the nonsparking type, *see Pt 5, Ch 13, 1.8 Non-sparking fans for hazardous areas*.

1.10.5 Provision is to be made for closing the air intake and extraction ducts in case of fire. The means provided are to be capable of operation from the deck.

1.10.6 For type N-open tankers natural ventilation is acceptable.

■ *Section 2*
Piping systems for bilge, ballast, fuel oil, etc.

2.1 Pumping arrangements at ends of ship

2.1.1 The pumping arrangements in the machinery space and at the forward end of the ship are to comply with the requirements for general cargo ships, in so far as they are applicable, and with the special requirements detailed in this Section.

2.1.2 Bilge, ballast and fuel oil lines, etc. which are connected to pumps, tanks or compartments at the ends of the ship, are not to pass through cargo tanks or have any connections to cargo tanks.

2.1.3 The fuel oil bunkering system is to be entirely separate from the cargo handling system.

2.1.4 Where non-permanent connections are required in piping systems between non-hazardous and hazardous spaces, two means of isolation are to be provided. One of these means is to provide positive separation by means of a removable spool piece or flexible hose, and blank flanges are to be fitted. The other is to be a non-return valve, or similar, in accordance with an acceptable national or international Standard that is appropriate for the design conditions of the piping system. The non-return valve and removable piece are to be located within the existing hazardous spaces. A notice is also to be provided located in a prominent position adjacent to the means of isolation, clearly indicating that the spool piece or flexible hose is to be removed, and blanking flanges are to be fitted, when the piping is not in use. The removable spool piece is to be clearly identified (labelled/painted in a distinctive colour) and stowed close to its working position.

2.2 Drainage and/or ballasting of spaces within the cargo zone

2.2.1 Provision is to be made for the bilge drainage of under deck cargo pump-rooms by pump or bilge ejector suctions. The pump-room bilges of small tankers may be drained by means of a hand pump having a 50 mm bore suction. Pump-room suctions are not to enter machinery spaces. In case of emergency the pump-room is to be drained by a bilge unit situated outside the pump-room and independent of all other installations in the cargo zone.

2.2.2 For all tankers, a bilge alarm is to be fitted in under deck pump-rooms which will activate a visual and audible alarm in the wheelhouse to warn that the liquid in the pump room bilge has reached a predetermined level.

2.2.3 Bilge or ballast pumps serving spaces within the cargo zone other than cargo tanks are to be placed in that zone and their piping systems are to be separate from any other piping system. For exemptions, *see Pt 5, Ch 13, 2.2 Drainage and/or ballasting of spaces within the cargo zone 2.2.10*.

2.2.4 For all tankers, arrangements are to be made to fill the cofferdams by means of a pump. The filling is to be carried out within 30 minutes. Provision is to be made to prevent the cofferdams being subjected to a pressure which is in excess of that for which the cofferdams have been constructed.

2.2.5 For ships required to comply with the ADN Regulations and provided with an A-60 bulkhead insulation as per *Pt 5, Ch 13, 1.6 Cargo pump-room 1.6.2*, filling of the cofferdam may be waived.

2.2.6 For cofferdams arranged as service space the requirements of *Pt 5, Ch 13, 2.2 Drainage and/or ballasting of spaces within the cargo zone 2.2.4* may be waived.

2.2.7 Cofferdams may be drained by a pump situated in the cargo zone. Alternatively, they may be drained by bilge ejectors.

2.2.8 Cofferdams are not to have any direct connections to the cargo tanks or cargo lines.

2.2.9 Cofferdam pipe systems are to be independent from any other pipe system of the ship.

2.2.10 Bilge or ballast pumps serving spaces within the cargo zone other than cargo tanks may be placed outside that zone only under the following conditions:

- All Types of tankers; for wing tanks and double bottom tanks not having a common boundary with the cargo tanks.
- Type G tankers; for cofferdams and hold spaces containing cargo tanks if ballasting will be carried out through a flexible connection with the fire main. Upon completion of the ballast operation, the fire main must be disconnected from the relevant spaces. The cofferdams and hold spaces are to be drained by bilge ejectors.
- Type N & C tankers; for cofferdams, wing tanks, double bottom tanks and hold spaces containing cargo tanks if ballasting will be carried out through a flexible connection with the fire main. Upon completion of the ballast operation, the fire main must be disconnected from the relevant spaces. The cofferdams and hold spaces are to be drained by bilge ejectors.

As an alternative to a flexible connection, a fixed connection with a spectacle flange could be accepted. Upon completion of the ballast operation the fire main must be separated from the relevant spaces by fitting the spectacle flange in the ‘closed’ position.

2.2.11 The shipside connection for ballast pumps placed in the cargo zone is to be situated within that zone but outside the cargo tanks.

2.2.12 Where bilge and ballast pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands of an approved type are to be fitted as per *Pt 5, Ch 13, 3.2 Cargo pumps and compressors 3.2.5*. *See also Table 13.1.1 Alarms and safety arrangements*.

2.2.13 Bilge systems for hold spaces containing independent cargo tanks are to comply with *Pt 5, Ch 13, 2.2 Drainage and/or ballasting of spaces within the cargo zone 2.2.14* .

2.2.14 The diameter d_b of the bilge line suction pipe is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2.0\ C\ (B + D) + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm

C = length of compartment, in metres

B = Breadth of the hold space, in metres

D = Depth of the compartment, in metres.

2.2.15 Calculation of the minimum required bilge capacity is to be in compliance with *Pt 5, Ch 11, 6.3 Capacity of pumps*.

2.2.16 If the volume of the cargo tank exceeds 75 per cent of the total volume of the hold space the bilge capacity may be reduced by 50 per cent.

2.2.17 The minimum required bilge capacity is to be not less than 12.5 m^3/h.

2.3 Air and sounding pipes

2.3.1 Cofferdams are to be provided with not less than two air pipes each in order to obtain a reasonable circulation of air. One of the air pipes is to be led near the bottom of the cofferdam. Sounding pipes on the cofferdam are to be led to the open deck. The air pipes, except for Type N-open Tankers, are to be fitted with a wire gauze diaphragm at their outlets, of an approved type and capable to resist a deflagration.

2.3.2 Double bottom tanks and wing tanks in the cargo area intended for ballast purposes are to be provided with an air pipe as per *Pt 5, Ch 11, 10 Air and sounding pipes*. Sounding pipes on the cofferdam are to be led to the open deck.

2.3.3 Hold spaces containing independent cargo tanks are to provided with not less that two air pipes. The diameter and position of the air pipes are to be such that each place in the hold will be sufficiently ventilated.

2.3.4 Alternatively the above hold spaces are to be inerted or filled with dry air if air pipes are not provided.

2.3.5 The following tanks and voids in the cargo area are to be ventilated by a suitable appliance:

(a) Double bottom tanks not intended for ballast purposes.
(b) Wing tanks not intended for ballast purposes.
(c) Cofferdams other than mentioned in *Pt 5, Ch 13, 2.3 Air and sounding pipes 2.3.1*.
(d) Hold spaces containing independent cargo tanks for Type C and N tankers.

2.4 Double bottom tanks below cargo tanks and wing tanks

2.4.1 Where double bottom tanks are fitted below cargo tanks and for wing tanks, the requirements of *Pt 5, Ch 13, 2.2 Drainage and/or ballasting of spaces within the cargo zone 2.2.7* are applicable. For air and sounding pipes *see Pt 5, Ch 13, 2.3 Air and sounding pipes 2.3.2*.

2.4.2 Double bottom tanks below cargo tanks and wing tanks may be used for ballast purposes only.

2.4.3 For ships having hold spaces containing cargo tanks, double bottom tanks may be used as fuel oil tanks provided:

- the height of the double bottom tank is not less than 0,60 m.
- fuel oil pipes and openings of these tanks are not fitted or terminating in the hold spaces.
- air pipes are led to the open deck with a height of not less than 0,60 m above deck.
- air pipes are fitted with a wire gauge as per *Pt 5, Ch 11, 10.6 Gauze diaphragms*.

■ *Section 3* Cargo handling system

3.1 General

3.1.1 A complete system of piping and pumps is to be fitted for dealing with the cargo.

3.1.2 Arrangements for emptying tanks by means of applying pressure above the cargo or by other methods will be specially considered.

3.1.3 Connections should be made for the gas freeing of the cargo tanks, when the cargo has been discharged, and for the ventilation and gas freeing of all compartments adjacent to cargo tanks.

3.1.4 Where gas freeing arrangements are provided, fans are to be installed in the cargo zone. The fans are to be of nonsparking material except for Type N-open. *See also Pt 5, Ch 13, 1.8 Non-sparking fans for hazardous areas*. Where driving motors are electrical and are situated in the cargo zone, they are to be of the certified safe type, *see Pt 6, Ch 2, 13.8 Certified safe type equipment*. Otherwise the fan prime mover is to be installed outside the hazardous area in an enclosed space. Where the driving shaft penetrates the bulkhead it is to do so via an approved gastight seal, *see also Pt 5, Ch 13, 3.2 Cargo pumps and compressors 3.2.5*.

3.1.5 Access hatches and all other openings to cargo tanks, such as ullage and tank cleaning openings are to be located on deck.

3.1.6 Ships carrying toxic products are to be equipped with at least one instrument designed and calibrated for testing for the vapours. For measuring flammable products, *see Pt 5, Ch 13, 5.7 Gas measurement*.

3.2 Cargo pumps and compressors

3.2.1 Pumps for the purpose of filling or emptying the cargo tanks or compressors pumping cargo gas back to shore or to re-liquefy cargo vapour and return it to the cargo tanks are to be used exclusively for this purpose and are to be situated in the cargo zone. They are not to have any connections to compartments outside the range of cargo tanks. This is not applicable for Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8.

3.2.2 Means are to be provided for stopping the cargo pumps or compressors from a position outside the cargo zone, as well as at the pumps, or compressors.

3.2.3 Pump suction and discharge pressure gauges are to be provided at the pumps or compressors (except for the suction side of deep well pumps). The pressure gauges are to be readable at the pump control stations at all times.

3.2.4 The pumps or compressors are to be provided with effective relief valves which are to be in close-circuit, i.e. discharging to the suction side of the pumps. Alternative proposals to safeguard against over-pressure on the discharge side of the pump will be specially considered.

3.2.5 Where cargo pumps are driven by shafting which passes through a pump-room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump-room plating. The glands are to be efficiently lubricated from outside the pump-room. The seal parts of the glands are to be of materials that will not initiate sparks. The glands are to be of an approved type and are to be attached to the bulkhead in accordance with *Pt 5, Ch 11, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)*. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 3,4 bar before fitting. Bulkhead penetrations with nitrogen seals with an air back up will be specially considered.

3.2.6 Where cargo pumps are driven by hydraulic motors which are located inside cargo tanks, the design is to be such that contamination of the operating medium with cargo liquid cannot take place under normal operating conditions.

3.2.7 Pumps and compressors situated on deck are to be fitted in a position not less than 6 m away from entrances and openings of accommodation and service spaces outside the cargo zone. This is not applicable to Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8.

3.3 Cargo piping systems

3.3.1 Cargo pipes are to be situated in the cargo zone and are not to pass through cofferdams or through tanks or compartments which are outside the cargo zone and are to be completely separate from any other piping system. This is not applicable for Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8. Cargo pipes are to be clearly marked to distinguish them from other piping systems.

3.3.2 Means are to be provided to enable the contents of the cargo lines and pumps to be drained to a cargo tank or other suitable tank. Where drain tanks are fitted in pumprooms, they are to be of the closed type with air and sounding pipes led to the open deck.

3.3.3 For bunkering vessels where the contents of the cargo lines in way of the connection with the bunkering gig could not be drained as indicated above separate drainage arrangements are to be provided.

3.3.4 Suitable provision for expansion is to be made, where necessary, in the cargo pipe lines as follows;

- Type G tankers are to be provided with bends. Alternatively, expansion bellows of approved type may be fitted, *see Pt 5, Ch 10, 9.7 Expansion bellows*.
- Type C and N tankers are to be provided with expansion joints of approved type or bends, *see Pt 5, Ch 11, 2.7 Provision for expansion 2.7.2* and *Table 10.2.5 Application of mechanical joints* in Chapter 10.
- Tankers carrying only cargoes listed in *Pt 4, Ch 6, 10.1 General 10.1.1* may be provided with mechanical joints of the slip-on type, *see Table 10.2.5 Application of mechanical joints* in Chapter 10.

3.3.5 Stainless steel expansion bellows used in piping systems are to be protected against over extension and compression and adjoining pipes are to be suitably supported and anchored. Reference is made to recognised Standards such as EJMA & BS6129 Pt 1 for acceptable methods of support and anchoring.

3.3.6 No cargo piping may be arranged under deck, except inside cargo tanks and pump rooms. This is not applicable for Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8.

3.3.7 All cargo pipes and their associated fittings are to be tested after assembly on board by hydraulic pressure as per *Pt 5, Ch 10, 8 Hydraulic tests on pipes and fittings*. In no case is the hydraulic test pressure to be less than 10 bar.

3.3.8 Type C and N tankers are to be provided with a fixed installed stripping system. *See also Pt 5, Ch 13, 1.4 Design 1.4.6*.

3.3.9 Loading and discharge lines for Type C tankers, with the exemption of the shore connections, are to be so arranged that no part is situated nearer the side of the ship than B/4.

3.3.10 The loading and discharge lines and vapour collecting lines for Type G tankers, with the exemption of the shore connections but including the safety valves, are to be arranged, together with the relevant segregation devices and valves, between the outside boundary of the dome and B/4.

3.3.11 The above is not applicable to safety discharge pipes. If, however only one dome is present at centre line ship these pipes are to be situated at a minimum distance from the shipside of not less than 2.7 m.

3.3.12 The requirements of *Pt 5, Ch 13, 3.3 Cargo piping systems 3.3.13* to *Pt 5, Ch 13, 3.3 Cargo piping systems 3.3.18* apply to product and process piping including vapour piping and vent lines of safety valves or similar piping intended for Type G tankers.

3.3.13 All pipelines or components which may be isolated in a liquid full condition should be provided with relief valves.

3.3.14 Consideration will be given to a relaxation of the above requirement for pipe sections with a volume of 50 litres, or less.

3.3.15 Relief valves discharging liquid cargo from the cargo piping system should discharge into the cargo tanks.

3.3.16 The nominal thickness of steel pipes is to be not less than shown in *Table 13.3.1 Nominal thickness steel pipes* for the appropriate standard pipe size. Stainless steel pipes will receive special consideration.

Table 13.3.1 Nominal thickness steel pipes

Standard pipe sizes outside diameter, in mm		Minimum over-riding normal thickness in mm
Exceeding	Not exceeding	
–	10,2	1,6
10,2	17,2	1,8
17,2	26,9	2,0
26,9	33,7	2,3
33,7	54,0	2,6
54,0	76,1	2,9
76,1	88,9	3,2
88,9	114,3	3,6
114,3	139,7	4,0
139,7	168,3	4,5
168,3	193,7	5,4
193,7	219,1	5,9
219,1	279,0	6,3
279,0	323,9	7,1
323,9	368,0	8,0
368,0	419,0	8,8

3.3.17 Flanges, valves and other fittings should comply with recognised Standards, taking into account the maximum applicable gauge pressure. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted.

3.3.18 For flanges not complying with a standard, the dimensions of flanges and related bolts will be specially considered.

3.3.19 Ships fitted with a bunker mast in compliance with *Pt 4, Ch 6, 10 Bunkermasts* shall be provided with a spool piece in the discharge pipe(s) to the hose(s) of the bunker mast. This spool piece is to be removed and blanking flanges are to be fitted if cargoes other than those listed in *Pt 4, Ch 6, 10.1 General 10.1.1* are carried. A notice is to be provided, located in a prominent position, clearly indicating when the spool piece is to be removed.

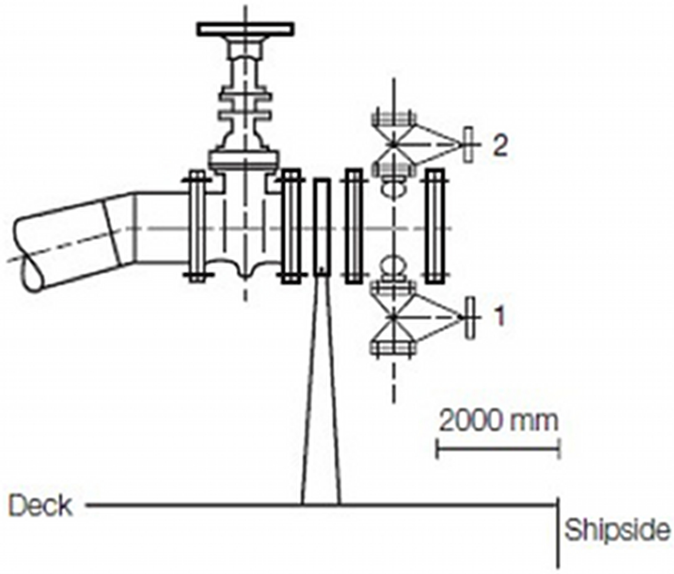
3.4 Terminal fittings at cargo loading stations

3.4.1 Terminal pipes, valves and other fittings in the cargo loading, discharging and vapour return lines, to which shore installation hoses are connected, are to be steel or approved ductile material from the point of connection up to and including the terminal valves. They are to be of robust construction and strongly supported, *see also Pt 5, Ch 13, 1.3 Materials* and *Pt 5, Ch 13, 1.4 Design*.

3.4.2 Shore connections of the cargo loading, discharging and vapour return lines are to be provided with a valve. When not in use, they are to be provided with a blind flange.

3.4.3 For Type G tankers, one remotely operated emergency shutdown valve (quick closing valve) is to be provided in addition to the valve as per *Pt 5, Ch 13, 3.4 Terminal fittings at cargo loading stations 3.4.2*. Control of this valve is to be from positions fore and aft of the ship, *see also Pt 5, Ch 13, 3.7 Remote control valves 3.7.6*.

3.4.4 The cargo loading and discharge lines in way of the cargo loading station for Type C and N tankers are to be provided with a connection as per *Figure 13.3.1 Connection for the delivery of residual cargoes*.



1. Connection for delivery of residual cargo
   Connection conform CEFIC
2. Connection for the shore installation to discharge the residual cargo by means of gas pressure
   Connection conform CEFIC

CEFIC stands for European Chemical Industry Council

Figure 13.3.1 Connection for the delivery of residual cargoes

3.4.5 Bunker ships or other ships capable of discharging fuel oil, lubricating oil, hydraulic oil, etc. to other ships are to be provided with a quick closing valve of ductile material in the discharge pipe. The valve is to be capable of being closed independent of the remote control, *see also Pt 5, Ch 13, 3.7 Remote control valves*.

3.4.6 The valve closure time required in the above paragraph is to be such as to avoid surge pressures in the piping system. The valve closure time is to be verifiable and reproducible.

3.4.7 Shore connections shall be located not less than 6,0 m from entrances to, or openings of, the accommodation and service spaces outside the cargo area. This requirement is not applicable to ships of Type N-open with the exemption when corrosive liquids of Class 8 will be carried.

3.4.8 The distance required by *Pt 5, Ch 13, 3.4 Terminal fittings at cargo loading stations 3.4.7* may be reduced to 3,0 m subject to the requirements of *Pt 4, Ch 4, 3.3 Protection against the ingress of gases within accommodations and entrances 3.3.3*.

3.5 Cargo segregation

3.5.1 Piping systems which serve tanks containing incompatible cargoes are to be isolated from each other by means of removable pipe lengths and blank flanges. Isolating shut-off valves, single or double, or spectacle flanges are not acceptable as equivalent arrangements.

3.5.2 Blind Flange Valves of an approved type are acceptable as an equivalent means of segregation in cargo systems.

3.5.3 Spectacle Flanges could be accepted in vapour return systems except for tankers carrying toxic cargoes Class 6.1.

3.5.4 Cargoes, residues of cargoes or mixtures containing cargoes which react in a hazardous manner with other cargoes, residues or mixtures should:

(a) be segregated from such other cargoes by means of a cofferdam void space, cargo pump room, pump-room, empty tank or tank containing a mutually compatible cargo;
(b) have separate pumping and piping systems which should not pass through other cargo tanks containing such cargoes, unless encased in a tunnel; and
(c) have separate tank venting systems.

3.6 Connections to cargo tanks

3.6.1 Where cargo tanks are provided with direct filling connections, the loading pipes are to be led to as low a level as practicable inside the tank.

3.6.2 Where cargo suction and/or filling lines are led through cargo tanks, the connection to each tank is to be provided with a valve secured to the bulkhead and situated inside the tank it serves, and capable of being operated from the deck. Cargo compatibility is to be assured in the event of pipe failure, (*see Pt 5, Ch 13, 3.5 Cargo segregation 3.5.4.(b)*). Where a pump can be used for more than one cargo tank, shut-off valves are to be provided in the pump-room. For Type N tankers this valve is to be fitted not less than 0,60 m above the bottom.

3.6.3 Cargo lines on Type G tankers are not to be used for ballast purposes.

3.6.4 For Type C and N tankers, the piping system is to be so arranged that water for cleaning out the cargo tanks or for ballasting the ship, is to be taken from a suction pipe situated inside the cargo zone but outside the cargo tanks. At the junction with the cargo filling pipes a screw-down non-return valve is to be fitted.

3.6.5 On Type C or N tankers, pumps for tank wash systems, including their co

- The discharge side of the system is arranged such, that suction through this pipeline is not possible.
- A spring loaded non-return valve, is to be fitted in the discharge pipe when entering the cargo zone.

3.6.6 The connections on the tank domes for Type G tankers with two cargo tanks situated side by side are to be arranged at the dome part facing the centre line of the ship only. Connections positioned at the centre line dome parallel to the centre line of the ship are acceptable accordingly. The valves are to be fitted as close as practicable to the dome.

3.6.7 All liquid and vapour connections on Type G tankers at each cargo tank dome, except safety relief valves and liquid level gauging devices are to be equipped with a manually operated stop valve and a remotely controlled emergency shutdown valve. These valves are to be located as close to the tank as practicable. Where the pipe size does not exceed 50 mm in diameter, excess flow valves may be used in lieu of the emergency shutdown valve.

3.7 Remote control valves

3.7.1 Valves which are provided with remote control are, in general, to be arranged for local manual operation independent of the remote operating mechanism, *see also Pt 5, Ch 11, 2.3 Valves - Installation and control 2.3.2*.

3.7.2 Where the valves and their actuators are located inside the cargo tanks, hydraulic (not pneumatic) means for operating the valve actuators are to be provided.

3.7.3 Emergency means are to be provided for operating the valve actuators in the event of damage to the main hydraulic circuits on deck. This could be achieved by ensuring that the supply lines to the actuators are led vertically inside the tanks from deck, and that connections, with the necessary isolating valves, are provided on deck for coupling to a portable pump carried on board.

3.7.4 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium. Indication is to be provided at the remote control station showing whether the valve is open or shut.

3.7.5 Materials of construction of the actuators and piping inside the cargo tanks are to be suitable for use with the intended cargoes. *See Pt 5, Ch 13, 1.3 Materials*.

3.7.6 The control system for all required emergency shutdown valves is to be so arranged that all such valves may be operated by single controls situated in at least two remote locations on the ship. One of these locations is to be from a position from which all the cargo tanks can be controlled or from the cargo control room.

3.8 Flanges and glands

3.8.1 On Type C tankers, flanges in cargo lines and glands on cargo tanks or lines are to be fitted with adequate arrangements to prevent any accidental spray of cargo.

3.8.2 On Type N tankers, flanges in cargo lines and glands on cargo tanks or lines are to be fitted with adequate arrangements to prevent any accidental spray of cargo when it is intended to carry corrosive cargoes.

3.9 Ship's cargo hoses

3.9.1 Liquid and vapour hoses, used for cargo transfer should be compatible with the cargo and suitable for the cargo temperature.

3.9.2 Details of such hoses are to be submitted together with a type test certificate issued by a recognised Authority.

3.9.3 Hoses subject to tank pressure or the discharge pressure of the pumps should be designed for a bursting pressure of not less than 5 times the maximum pressure the hose will be subjected to during cargo transfer.

3.9.4 Each new type of cargo hose, complete with end fittings should be prototype-tested to a pressure not less than 5 times its specified maximum working pressure. The hose temperature during this prototype test should be the highest and/or lowest service temperature for which the hose is intended.

3.9.5 Hoses used for prototype testing should not be used for cargo service.

3.9.6 Thereafter, before being placed in service, each new length of cargo hose should be hydrostatically tested at ambient temperature to a pressure not less than 1,5 times its specified maximum working pressure but not more then two-fifths of its bursting pressure.

3.9.7 The hose should be stencilled or otherwise marked with the date of testing, its specified maximum working pressure and, if used in other than ambient temperature services, its maximum and minimum service temperature as applicable.

3.9.8 The specified maximum working pressure should be not less than 10 bar gauge.

3.9.9 For Type G tankers, *Pt 5, Ch 13, 3.9 Ship's cargo hoses 3.9.10* to *Pt 5, Ch 13, 3.9 Ship's cargo hoses 3.9.13* will also be applicable.

3.9.10 Each new type of cargo hose, complete with end fittings, should be prototype-tested at a normal ambient temperature with 200 pressure cycles from zero to at least twice the specified maximum working pressure.

3.9.11 After this cycle test pressure has been carried out, the prototype test should demonstrate a bursting pressure as per *Pt 5, Ch 13, 3.9 Ship's cargo hoses 3.9.3* and *Pt 5, Ch 13, 3.9 Ship's cargo hoses 3.9.4*.

3.9.12 It is assumed that the hoses referred to are ship-toshore or ship-to-ship hoses which are traditionally considered to be outside the scope of classification. The design, construction and testing of such hoses are to be for the relevant National or Port Authority to approve.

3.9.13 Materials having a melting point below 925°C should not be used for piping outside the cargo tanks except for short lengths of pipe attached to the cargo tanks, in which case fire-resisting insulation should be provided. This temperature limitation indicates that any hoses for use in cargo systems on board ship are to be of metallic construction having a melting point higher than 925°C.

3.9.14 For general requirements on rubber hoses, *see Pt 5, Ch 10, 7 Flexible hoses*.

3.10 Slop tanks and vessels intended for slops for Type C tankers and Type N tankers

3.10.1 Type C and N tankers are to be provided with at least one slop cargo tank and, so far as applicable, with drums for slops which cannot be pumped.

3.10.2 Slop tanks and drums, intended for slobs, are to be located in the cargo zone only.

3.10.3 IBCs (Intermediate Bulk Containers) or portable tanks may be used instead of a fixed residual cargo tank based on special consideration.

3.10.4 Slop tanks For Type N closed tankers and Type C tankers are to be provided with:

- A high velocity valve in compliance with *Pt 5, Ch 13, 5.1 General 5.1.2* as far as applicable.
- A vacuum valve in compliance with *Pt 5, Ch 13, 5.1 General 5.1.2* as far as applicable.
- A vacuum valve in compliance with *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(e)* when explosion protection is required as per the ADN Table C, Column 17.
- A high velocity vent valve in compliance with *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(c)* when explosion protection is required as per the ADN Table C, Column 17.
- A sounding device of approved type.
- Connections with valves intended for pipes and hoses.

3.10.5 Slop tanks For Type N-with wire gauze tankers are to be provided with:

- A flame arresting pressure equilibrium device.
- A sounding opening.
- Connections with valves intended for pipes and hoses.

3.10.6 Slop tanks for Type N open tankers are to be provided with:

- A pressure equilibrium device.
- A sounding opening.
- Connections with valves intended for pipes and hoses.

3.10.7 IBCs or tank containers for collecting slobs are to be provided with:

- A connection for venting gases in a safe manner during filling operations.
- A sounding arrangement of approved type.
- Connections with valves intended for pipes and hose

3.10.8 Slop tanks, IBCs and tank containers are not to be connected to the vapour return system of the cargo tanks except in case the slob tanks or containers are filled.

3.10.9 Slop tanks shall not be connected to a common pipe system when incompatible cargoes will be carried simultaneously, *see Pt 5, Ch 13, 3.5 Cargo segregation*.

■ *Section 4*
Cargo tanks for Type G tankers

4.1 General

4.1.1 Pressure vessels intended for Type G tankers are independent tanks of the domed type. Fittings for the cargo piping system are to be mounted on the domes above the open deck (*see Pt 5, Ch 13, 3.6 Connections to cargo tanks 3.6.6*) All instrumentation and other connections are to be also accessible from the open deck.

4.1.2 The tanks are to be provided with at least one manhole with access from the open deck

4.1.3 The pressure vessels are to comply with *Pt 5, Ch 13, 4.2 Cargo tank design* to *Pt 5, Ch 13, 4.10 Stress relieving independent tanks* and, as far as applicable with the requirements of *Ch 4 Cargo Containment* for independent Type C tanks of the Rules for Ships for Liquefied Gases.

4.2 Cargo tank design

4.2.1 Scantlings based on internal pressure should be calculated as follows:

(a) The thickness and form of pressure-containing parts of pressure vessels under internal pressure, including flanges should be determined according to an acceptable standard. These calculations in all cases should be based on generally accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels should be reinforced in accordance with an acceptable standard.

(b) The design liquid pressure defined in *Pt 5, Ch 13, 4.3 Design loads 4.3.2* should be taken into account in the above calculations.
(c) The welded joint efficiency factor to be used in the calculation according to *Pt 5, Ch 13, 4.2 Cargo tank design 4.2.1*(a) is depending on inspection and non-destructive testing requirements. See for guidance the Rules for Liquefied Gases *Part E - Tank Types*.
(d) The maximum volume of a cargo tank is to comply with *Pt 4, Ch 4, 3.2 Hold spaces, cargo tanks and service spaces*
(e) The length to diameter ratio of a cargo tank is not to exceed 7, *see Pt 4, Ch 4, 3.5 Special requirements for Type G tankers 3.5.1*

4.3 Design loads

4.3.1 **General**. The independent tanks together with the supports and other fixtures should be designed taking into account proper combinations of the following loads:

- Internal pressure
- External pressure
- Loads on supports

4.3.2 **Internal pressure.** The internal pressure head P_{eq} in bars gauge resulting from the design vapour pressure P_o and the liquid pressure P_{gd} should be calculated as follows:

$$P_{eq} = P_o + (P_{gd})_{max} \text{ (bar)}$$

4.3.3 **External pressure.** External design pressure loads should be based on the difference between the maximum internal pressure (maximum vacuum) and the maximum external pressure to which any portion of the tank may be subjected simultaneously.

4.3.4 The loads on supports are covered by the *Pt 5, Ch 13, 4.6 Supports*.

4.4 Design temperature

4.4.1 The design temperatures for the calculations and selection of materials is to be as follows:

- The design temperature, *T*, for calculation purposes is to be not less than 50°C.
- A minimum temperature is to established for the selection of materials, *see Pt 5, Ch 13, 5.4 Design temperature for Type G tankers 5.4.1*.

4.5 Allowable stresses

4.5.1 For independent tanks the maximum allowable membrane stress to be used in the calculation according to *Pt 5, Ch 13, 4.2 Cargo tank design 4.2.1*(a) will be specially considered.

4.5.2 For guidance reference is made to the Rules for Ships for Liquefied Gases *Part E - Tank Types*.

4.6 Supports

4.6.1 Cargo tanks should be supported by the hull in a manner which will prevent bodily movement of the tanks while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and of the hull.

4.6.2 Tank supports are generally to be located in way of the primary structure of the tank and the ship's hull. Steel seatings are to be arranged, where possible on both the floors and underside of the cargo tank so as to ensure an effective distribution of the transmitted load and reactions into the cargo tanks and ship's structure.

4.6.3 Suitable supports should be provided to withstand a collision force acting on the tank corresponding to half the weight of the tank and cargo in the forward direction and one quarter of the weight of the tank and cargo in the aft direction without deformation likely to endanger the tank structure.

4.6.4 Anti flotation arrangements should be provided for independent tanks. The anti flotation arrangements should be suitable to withstand an upward force caused by an empty tank in a hold space flooded to T_{max} + 0.4 m in which T_{max} is the maximum draught of the ship, without plastic deformation likely to endanger the hull structure.

4.6.5 An adequate clearance is to be provided between the anti flotation chocks and the ship's hull in all operational conditions.

4.6.6 The support arrangements should be designed for the full weight of the tanks together with holding down arrangements.

4.6.7 The tank seatings shall be capable to keep the tank in place for a total heeling range up to and including the total capsised condition.

4.6.8 The saddles are to be extended to a point of not less than 10º below the horizontal centre line of the pressure vessel.

4.7 Construction and testing

4.7.1 All welded joints of the shells of independent tank should be of the butt weld, full penetration type.

4.7.2 Manufacture and workmanship are to satisfy the requirements of *Ch 13, 1 General welding requirements* of the Rules for Materials for Class 1 pressure vessels.

4.7.3 Independent tanks should be subjected to a hydrostatic test or alternatively to a hydro pneumatic test as per Chapter 4, Section *Part E - Tank Types* for Type C independent tanks of the Rules for Ships for Liquefied Gases.

4.8 Inspection and non-destructive testing

4.8.1 For independent tanks, inspection and nondestructive testing should be as far as applicable in compliance with Chapter 4, Section *Part E - Tank Types* of the Rules for Ships for Liquefied Gases and the requirements of *Ch 13, 4 Specific requirements for fusion welded pressure vessels* of the Rules for Materials for Class 1 pressure vessels.

4.9 Corrosion Allowance

4.9.1 For pressure vessels no corrosion allowance is generally required if the contents of the pressure vessel are non-corrosive and the external surface is protected by inert atmosphere or by an appropriate insulation with an approved vapour barrier. Paint or other thin coatings should not be credited as protection. Where special alloys are used with acceptable corrosion resistance, no corrosion allowance should be required. If the above conditions are not satisfied, the scantlings calculated according to *Pt 5, Ch 13, 4.2 Cargo tank design* should be increased as appropriate.

4.10 Stress relieving independent tanks

4.10.1 For independent tanks of carbon and carbon-manganese steel, post-weld heat treatment should be performed after welding. The post-weld heat treatment is to conform to the requirements of *Ch 13, 4.10 Post-weld heat treatment* and *Ch 13, 4.11 Basic requirements for post-weld heat treatment of fusion welded pressure vessels* in the Rules for Materials. For all carbon and carbon-manganese steel tanks requiring heat treatment, the requirements of *Table 13.4.2 Post-weld heat treatment requirements* in the Rules for Materials are to be complied with.

■ *Section 5*
Cargo tank venting arrangements

5.1 General

5.1.1 Each cargo tank and slop tank or group of cargo tanks or slop tanks connected by means of a vapour collecting pipe system is to be fitted with venting arrangements which will limit the pressure or vacuum in the tank, and are to comply with the requirements of this Section. The vapour collecting system of slop tanks are normally separated and distinct from the cargo tanks, *see Pt 5, Ch 13, 3.10 Slop tanks and vessels intended for slops for Type C tankers and Type N tankers 3.10.8*.

5.1.2 Cargo tank venting arrangements are to be designed to provide:

(a) pressure/vacuum release of small volumes of vapour/air mixtures flowing during a normal voyage;
(b) venting of large volumes of vapour/air mixtures during cargo handling and gas freeing operations;
(c) Pressure sensors are to be fitted to monitor the overpressure and underpressure of the gas phase in each cargo tank protected by the arrangement required in *Pt 5, Ch 13, 5.1 General 5.1.2.(b)*, with a monitoring system in the ship's wheelhouse or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of overpressure or underpressure conditions within a tank. The alarm facility shall give a visible and audible alarm at the wheelhouse. If the wheelhouse is not supervised an additional alarm is to be provided at the position from which cargo operations are normally controlled.

5.2 Pressure/vacuum and venting systems for various tanker types

5.2.1 **Type N-open**. Each cargo tank is to be in open connection with the atmosphere through a vapour pipe, or equivalent, of sufficient cross-sectional area. Provision is to be made to prevent collection or the entrance of water into the cargo tanks by approved means or appliances.

5.2.2 **Type N-open, with flame arrestor**. Arrangements as for Type N-open ships, except that vapour pipes, or equivalent, are to be provided with readily renewable flame arrestors or safety heads of approved type suitable to withstand a long burning proof. Material of wire gauzes is to be resistant to corrosion. Provision is to be made to prevent collection or the entrance of water into the cargo tanks by approved means or appliances.

5.2.3 **Type C and N-closed.** Each cargo tank or group of cargo tanks connected to a common vapour pipe is to be provided with:

(a) means to prevent the tanks being subjected to an overpressure exceeding 115 per cent of the set pressure of the high velocity valve or to a design under pressure of the tanks. In any case, the under pressure is not to exceed 5 kPa during the voyage and any phase of the cargo handling;
(b) connections for returning the vapour to shore when loading cargo. These connections are to be provided with a positive means of closing, *see Pt 5, Ch 13, 3.4 Terminal fittings at cargo loading stations*;
(c) an approved type high velocity vent capable of resisting a long burning proof. Vapour should be discharged in an upward vertical direction.
(d) at each cargo tank connected to a common vapour pipe, a device should be fitted at the inlet of the vapour pipe to prevent the passage of flames and being capable of resisting a detonation in the common vapour pipe. The required device is to be of an approved type.
(e) a vacuum valve of an approved type and provided with a wire gauze capable of resisting a deflagration.
(f) a device of approved type to depressurise the cargo tanks in a safe manner. This device is consisting of a flame arrestor capable of resisting a long burning proof and a valve. The position of the valve i.e. open or closed is to be clearly indicated.
(g) high velocity vents to be arranged not less than 2 m above deck and their outlets should also be arranged at a distance of at least 6 m from the accommodation and service spaces positioned outside the cargo area. Openings below 2 m can be accepted provided no handling equipment will be fitted in a radius of 1 m and the area will be clearly marked as dangerous. In no case is the height of the opening to be less than 0,5 m above deck.
(h) a pressure gauge on each cargo tank suitable for under and over-pressure measurement. The over and under-pressure readings are to be visible at a position were loading or discharging can be stopped or otherwise from a position in the vicinity of the control of the water spray system. The maximum allowable under and over-pressure for the cargo tank is to be indicated on each pressure gauge. The pressure gauges readings are to be visible under all weather conditions.
(i) means for draining liquid in the vent piping system, from places where it may accumulate, should be provided. The high velocity valves and piping are to be so arranged that, under no circumstances, liquid can accumulate in or near the high velocity valves.
(j) If explosion protection is not required as per the ADN, Table C, Column 17 the following relaxations can be given:

- High velocity vents as per *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(c)* are not required to be of an approved long burning proof type.
- Vacuum valves as per *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(e)* are not required to be provided with a wire gauge capable of resisting a deflagration.
- Detonation devices as per *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(d)* are not required to be fitted.
- Depressurising devices are not to be provided with a flame arrestor capable of resisting a long burning proof as per *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(f)*.

(k) Flammable cargoes are banned from the list of dangerous goods for tankers in compliance with the above *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(j)*.

5.2.4 **Type G.** The requirements of *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.5* to *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.19* apply.

5.2.5 All cargo tanks are to be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold spaces and cargo piping which may be subjected to pressures beyond their design capabilities are also to be provided with a suitable safety relief system. The pressure safety relief system is to be connected to a vent piping system to minimise the possibility of cargo vapour accumulating about the deck or entering accommodation and machinery spaces, or any other space where it may create a dangerous condition.

5.2.6 Each cargo tank with a volume greater than 20 m^3 is to be fitted with at least two pressure relief valves of approximately equal capacity, suitably designed and constructed for the prescribed service. For cargo tanks with a volume less than 20 m^3, a single relief valve may be fitted.

5.2.7 The pressure relief valves should be connected to the highest part of the cargo tank above deck level.

5.2.8 In the vent piping system means, for draining liquid, from places where it may accumulate, should be provided. The pressure relief valves and piping are to be so arranged that, under no circumstances, can liquid accumulate in or near the pressure relief valves.

5.2.9 Pressure relief valves are to be prototype tested to ensure that the valves have the capacity required.

5.2.10 In general, the opening pressure of the safety valves should not be higher than the vapour pressure which has been used in the design of the tank. However, where two or more pressure relief valves are fitted, valves comprising not more than 50 per cent of the total relieving capacity may be set at a pressure up to 5 per cent above MARVS. (Maximum Allowable Relief Valve Setting of a cargo tank).

5.2.11 The setting of the pressure relief valves is in no case exceeding the maximum design pressure of the independent cargo tanks.

5.2.12 The pressure relief valves are to have a (combined) relieving capacity for each cargo tank as per *8.3 Additional pressure relieving system for liquid level control* and *8.5 Size of valves* of the Rules for Ships for Liquefied Gases.

5.2.13 Each tank is to be provided with a pressure gauge suitable for under and over-pressure measurement. The over and under-pressure readings are to be visible at a position were loading or discharging can be stopped. The maximum allowable under and over-pressure for the cargo tank is to be indicated on each pressure gauge. The pressure gauges are to be visible under all weather conditions.

5.2.14 For refrigerating systems, *see 7.2 Refrigeration systems*of the Rules for Ships for Liquefied Gases.

5.2.15 Each cargo tank in which cooled cargo will be carried is to be provided with a safety device which will prevent inadmissible over and under pressure in the cargo tanks.

5.2.16 For the carriage of cooled cargo, the opening pressure of the safety device is to be established by the arrangement of the cargo tank. For cargoes which are required to be cooled the safety device is to be set not less than 25 kPa above the calculated pressure as intended in *7.2 Refrigeration systems* of the Rules for Ships for Liquefied Gases.

5.2.17 Openings for the relief of gases from the overpressure devices are to be arranged not less than 2 m above deck and their openings should also be arranged of at least 6 m from accommodation and service spaces situated outside the cargo zone. A height of less than 2 m can be accepted provided no handling equipment will be fitted in a radius of 1 m of the discharge opening of the overpressure device and the area will be clearly marked as dangerous.

5.2.18 Suitable protection screens are to be fitted on vent outlets to prevent the ingress of foreign objects.

5.2.19 The design and testing of the devices mentioned in *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.2* to *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.17* are to comply with the requirements of the relevant National Authorities.

5.3 Design vapour pressure for Type G tankers.

5.3.1 The design vapour pressure P_o is the maximum gauge pressure at the top of the tank which has been used in the design of the tank.

5.3.2 For cargo tanks where there is no temperature control and where the pressure of the cargo is indicated only by the ambient temperature, P_o is not be less than the gauge vapour pressure of the cargo at a temperature of 40 °C.

5.3.3 In all cases, including *Pt 5, Ch 13, 4.3 Design loads 4.3.2*, P_o should not be less than MARVS.

5.4 Design temperature for Type G tankers

5.4.1 The design temperature for selection of materials is the minimum temperature at which cargo may be loaded or transported to the cargo tanks. Provisions to the Society's satisfaction are to be made to ensure that the tank or cargo temperature cannot be lowered below the design temperature.

5.5 Loading and unloading rates for Type C and Type N-closed tankers

5.5.1 Cargo tank venting systems should be designed and operated so as to ensure that neither pressure nor vacuum created in the cargo tanks during loading or unloading exceeds tank design parameters, *see Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(a)* for maximum allowable cargo tank pressures. The main factors to be considered in the sizing of a tank venting system are as follows:

(a) design loading and unloading rate;
(b) gas evolution during loading: this should be taken account of by multiplying the maximum loading rate by a factor of at least 1.25;
(c) density of the cargo vapour mixture, based on a mixture of 50 vol. per cent vapour and 50 vol. per cent air;
(d) pressure loss in the vent piping and across valves and fittings. Detonation devices and flame arrestors are to be considered in the clogged condition responsible for an additional pressure loss of not less than 30 per cent ;
(e) pressure/vacuum settings of relief devices;
(f) dimensions of the cargo tank venting system.

5.5.2 The maximum permissible loading and unloading rates for each tank or group of tanks consistent with the design of the venting system shall be carried on board.

5.5.3 The maximum permissible loading and unloading rates for each tank or group of tanks are to be limited in order to avoid static electricity, but should in any case not exceed 7 m/sec in the cargo pipes.

5.6 Pressure and temperature control of the cargo for a Type G tanker

5.6.1 Unless the entire cargo system is designed to withstand the full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, maintenance of the cargo tank pressure below the MARVS should be provided by one or more of the following means:

(a) A system which regulates the pressure in the cargo tank by the use of mechanical refrigeration.
(b) A system that accepts warming up and rise of pressure. The insulation together with the design pressure of the cargo tank are to be capable to guarantee an appropriate safety in respect of the period of operation and working temperature. The safety of at least three times the period of operation is to be guaranteed.
(c) Any other system acceptable to the Society.

For requirements of the above systems, *see Pt 5, Ch 13, 1.1 Application 1.1.8*.

5.6.2 The above systems should be constructed, fitted and tested to the satisfaction of the Society. Materials used in the construction should be suitable for use with the cargoes to be carried. For normal service, the upper ambient temperature should be:

- Air temperature : + 30 °C.
- Water temperature : + 20 °C.

5.6.3 For certain highly dangerous cargoes specified in Table C of the ADN , the cargo containment system should be capable of withstanding the full vapour pressure of the cargo under conditions of the upper ambient design temperatures irrespective of any system provided for dealing with boil-off gas, *see Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference.

5.7 Gas measurement

5.7.1 All tankers are to be equipped with at least one portable instrument for measuring the percentage of LEL of hydrocarbon concentrations in air, together with a sufficient set of spares.

5.7.2 All tankers are to be equipped with at least one portable oxygen analyser.

5.7.3 A sufficient set of spares of the above portable instruments is to be carried on board.

5.7.4 Suitable means are to be provided for the calibration of gas measurement instruments.

■ Section 6
Cargo tank level gauging equipment and arrangements against overfilling

6.1 Sounding devices

6.1.1 Each cargo tank is to be fitted with suitable means for ascertaining the liquid level in the tank.

6.1.2 Ullage openings or sighting ports may be fitted to the cargo tanks on Type N-open ships. *See Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.1* for requirements of openings in cargo tanks.

6.1.3 Arrangements which permit the escape of vapour to the atmosphere are not to be fitted in enclosed spaces.

6.1.4 Sounding information is to be available at the position where the valves of the cargo tank are controlled.

6.1.5 The maximum allowable filling limit of the cargo tank is to be indicated at each sounding device.

6.1.6 The sounding devices are to be legible under all weather conditions.

6.2 Closed level indicating devices

6.2.1 The cargo tanks of all types of ships are to be fitted with a closed level indicating device of an approved type. Except for Type N-open and N- with flame arrestors, the level indicating device is to be of the closed type which does not permit the escape of vapour or cargo when being used. For all types of tankers, the device is to be so positioned that it can be easily read from the operating position for the closing valve on the relevant tank.

6.2.2 Proposals to use indirect sounding or measuring devices, which do not penetrate the tank plating, will be specially considered.

6.3 Precautions against overfilling

6.3.1 Cargo tanks of each type of tanker are to be provided with a mark on the inside showing the level for the following maximum percentage of filling permitted, *see also Pt 5, Ch 13, 6.3 Precautions against overfilling 6.3.4*:

Type N	97%
Type C	95%
Type G	not applicable.

6.3.2 Cargo tanks of each type of tanker are to be provided with a high level audible and visual alarm set at the following percentage of filling, *see also Pt 5, Ch 13, 6.3 Precautions against overfilling 6.3.4*:

Type N	90%
Type C	90%
Type G	86%.

6.3.3 In addition to the high level alarm required by *Pt 5, Ch 13, 6.3 Precautions against overfilling 6.3.2* the tanks are to be provided with an independent automatic device for shutting off the supply of cargo, set at the following percentage of filling, *see also Pt 5, Ch 13, 6.3 Precautions against overfilling 6.3.4*:

Type N	97,5%
Type C	97,5%
Type G	97,5%.

6.3.4 Filling percentages are to be determined in relation to the total capacity of the tanks including any expansion trunk and are to have an accuracy of ±0,5 per cent.

6.3.5 For the maximum allowable cargo related filling limits *see* ADN Table C, Column 11, *see Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference.

6.3.6 Pressure vessels for Type G tankers may not be filled to more than 91 per cent for uncooled and 95 per cent for cooled cargoes. *See* ADN, Part 3, Table C, column 11, *see also Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference.

6.4 Cargo sampling arrangements

6.4.1 Cargo tanks of all ships are to be provided with suitable connections for a device capable of taking samples of the cargo.

6.4.2 On cargo tanks of Type G ships these devices are to be of the closed type.

6.4.3 On cargo tanks of Type C and N ships these devices are to be of the closed or restricted type. Conform with the requirements of ADN, Table C, Column 13, *see Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference. The sampling opening is to be in compliance with *Pt 5, Ch 13, 6.4 Cargo sampling arrangements 6.4.8*.

6.4.4 The closed devices are to be so arranged that loss of pressure and appreciable loss of gas is not possible.

6.4.5 The restricted devices are to be so arranged that during sampling only a minor quantity of gaseous or liquid cargo will come into the atmosphere. The arrangement of the device is such that it is completely closed when not used.

6.4.6 On cargo tanks of Type N-with flame arrestor a closed or partly closed sampling device is not required. However, sampling openings are to be in compliance with*Pt 5, Ch 13, 6.4 Cargo sampling arrangements 6.4.8*.

6.4.7 Closed or partly closed sampling devices and sampling openings are not required for Type N-open ships.

6.4.8 The diameter of sampling openings may not exceed 0,30 m. They must be provided with a flame arrestor and are to be so arranged that the opening time can be limited and the wire gauze could not remain in the open position without external influence.

6.4.9 On ships of Type N-Open sampling openings are not required to be fitted with a flame arrestor.

6.4.10 Sampling devices are not required for Type N bunker ships.

6.4.11 The cargo sampling devices are to be of an approved type, accepted by the applicable National Authorities.

■ *Section 7*
Cargo heating arrangements

7.1 General

7.1.1 In addition to the requirements detailed in this Section, the requirements of *Pt 5, Ch 12, 11 Thermal oil systems* for thermal oil systems to be installed on Type C and N tankers are to be complied with as far as they are applicable.

7.1.2 Outlets of exhaust gas lines from thermal oil heaters are to be provided with spark arrestors or equivalent and are not to be led through the cargo zone. The distance between the outlet and the cargo zone is to be not less than 2 m.

7.1.3 The air intakes from the thermal oil heater are to be so arranged that their openings are not less than 2 m outside the cargo zone and not less than 6 m from openings of cargo or slop tanks, cargo pumps on deck, openings of high velocity vents or over pressure devices and shore connections of the cargo lines. Furthermore, the air intakes are to be arranged not less than 2 m above deck.

7.1.4 Thermal oil heaters are to be situated in the engine room or, alternatively, in a special space outside the cargo zone accessible from deck or from within the engine room.

7.1.5 Where heating systems are provided for the cargo tanks, the arrangements are to comply with the requirements of *Pt 5, Ch 13, 7.2 Blanking arrangements* to *Pt 5, Ch 13, 7.5 Temperature indication*.

7.2 Blanking arrangements

7.2.1 Spectacle flanges or spool pieces are to be provided in the heating medium supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the cargo tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

7.3 Heating medium

7.3.1 The heating medium is to be compatible with the cargoes to be heated. Where a cargo is highly water reactive, water or steam is not to be used as the medium. For lists of chemicals containing information on water reactivity, *see* ADN, Table C, *see also Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference.

7.3.2 Where a combustible liquid is used as the heating medium, it is to have a flash point of 55°C or above (closed cup test).

7.3.3 In general, the temperature of the heating medium is not to exceed 220°C.

7.4 Heating circuits

7.4.1 The heating medium supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank, and the main supply lines are to be run above the deck.

7.4.2 Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank, and means are to be provided for regulating the flow.

7.4.3 In case of direct heating arrangements valves for the individual heating coils are to be provided with locking arrangements to ensure that the coils are under static pressure at all times.

7.4.4 For direct heating systems, isolation valves are to be provided in the cargo heating supply and return line in a readily accessible position in the cargo zone.

7.4.5 Where steam or water is employed in the heating circuits of Type N-open ships, the returns are to be led to an observation tank, which is to be in a well ventilated and well lighted part of the machinery space remote from highly heated surfaces or possible sources of ignition.

7.4.6 Where a thermal oil is employed in the heating circuits, the arrangements are to be such that contamination of the thermal oil with cargo liquid cannot take place under normal operating conditions.

7.4.7 A heat exchanger, situated in the cargo zone, is to be incorporated in the heating systems of tankers carrying toxic cargoes Class 6.1. In these cases the tank heating circuits are also to lie entirely within the cargo zone.

7.4.8 In any heating system a positive pressure in the coils of at least 30 kPa above the static liquid pressure of the cargo, increased with the relevant set pressure of the high velocity valve as far as applicable, shall be maintained under all conditions of service when the circulation pump is not in operation.

7.4.9 Alternatively, the heating system may be drained and blanked when the circuit is not in use, provided the heating system is to be verified on the presence of previous cargo at the commencement of heating another product.

7.4.10 Arrangements are to be provided to monitor the pressure in the heating coils.

7.4.11 In view of the dangerous situation which may arise in the event of contamination of the thermal fluid with low flash cargo oil, for oil and chemical tankers intended for the carriage of products having a flash point below 55°C, permanent notice boards should be displayed in prominent positions in the engine room and on deck, stating that the thermal oil system should remain under pressure, *see also Pt 5, Ch 13, 7.4 Heating circuits 7.4.8*, except when the ship is either carrying cargoes having a flash point above 55°C, or the cargo tanks are empty and gas free and will be pressurised again before low flash oil is loaded.

7.5 Temperature indication

7.5.1 Means are to be provided for measuring the cargo temperature. Where overheating could result in a dangerous condition, an alarm system which monitors the cargo temperature is to be provided.

■ *Section 8*
Cargo temperature control arrangements

8.1 Temperature measurement

8.1.1 All cargo tanks are to be fitted with cleary legible devices indicating the mean temperature of the cargo from a position where cargo operations are carried out.

8.1.2 For the maximum allowable temperature, *see* ADN, Table C , Column 20. *See also Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference, or as limited for tankers of Types C and N by *Pt 4, Ch 6, 1.7 Heated cargoes*.

8.2 Water spray system

8.2.1 Where settlement of vapour is required on Type G or Type C tankers, or cooling is required to retain the cargo temperature within the limits of safe carriage on Type N or Type C tankers, a water spray system with a capacity of not less than 50 litres/m^2 deck area cargo zone per hour is to be provided on deck.

8.2.2 This water spray system is to be capable of being connected to a shore supply.

8.2.3 The water spray system is to be controlled from the wheelhouse as well as on deck.

8.2.4 The water spray nozzles are to be arranged such that the deck area will be covered totally and for Type G and C tankers the releasing gases can be settled in a safe manner.

8.2.5 For cargoes for which a water spray system is mandatory, *see* list of chemicals in ADN, Table C, Column 9, *(see Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference).

■ *Section 9* Inert gas systems

9.1 General

9.1.1 Where an inert gas system is fitted, the arrangements are to comply with the following requirements and, as far as applicable, with the requirements of *Pt 5, Ch 15, 7 Inert gas systems on Tankers of 8,000 tonnes DWT and above* of the *Rules and Regulations for the Classification of Ships*. Consideration will be given to special cases where the arrangements are equivalent to those required by the Rules.

9.1.2 The space containing the Inert Gas generator is to be provided with visible and audible alarms for oxygen concentration. The sensors are to be located in positions where potentially dangerous concentrations may be readily detected.

9.1.3 The permeate outlet is to be led to a safe position as far as possible from any source of ignition. The pipe is of sufficient diameter in order to achieve very low velocities of the oxygen.

9.1.4 Spaces containing inert gas generating plants should have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces.

9.1.5 Inert gas piping should not pass through accommodation spaces, service spaces or control stations.

9.1.6 When not in use, the inert gas system should be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

9.1.7 Flame burning equipment for generating inert gas will be specially considered.

9.2 Type C tankers and Type N-closed tankers

9.2.1 One or more pressure-vacuum breaking devices are to be provided to prevent the cargo tanks from being subject to:

(a) a positive pressure in excess of the test pressure of the cargo tank if the cargo were to be loaded at the maximum rated capacity and all other outlets were left shut; and
(b) a negative pressure in excess of 5 kPa if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.

Such devices shall be installed on the inert gas main unless they are installed in the venting system required by *Pt 5, Ch 13, 5 Cargo tank venting arrangements* or on individual cargo tanks.

9.2.2 The set pressure of the vacuum valve required by *Pt 5, Ch 13, 5.2 Pressure/vacuum and venting systems for various tanker types 5.2.3.(e)* is to be 3.5 kPa.

9.2.3 The inert gas system is to be capable to maintain a pressure, under all conditions of service, of not less than 7 kPa in the tanks to be inerted.

9.2.4 Sufficient quantities of inert gas shall be available on board to compensate the losses during voyage.

9.2.5 Portable instruments for measuring oxygen and flammable vapour concentration are to be provided. In addition, suitable arrangement is to be made on each cargo tank such that the condition of the atmosphere can be determined using these portable instruments.

9.2.6 An Inert gas main is to be provided. The inert gas main may be divided into two or more branches forward of the deck main isolation valve.

9.2.7 The inert gas discharge may be connected with the vapour return system for ships carrying cargoes for which inert gas is not mandatory as per the ADN, Table C, Column 20, additional requirements (*see Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference). Two means of isolation as per *Pt 5, Ch 13, 9.2 Type C tankers and Type N-closed tankers 9.2.8* or *Pt 5, Ch 13, 9.2 Type C tankers and Type N-closed tankers 9.2.9* are to be provided in the connection to the vapour return line. In addition a removable spool piece is to be provided on the cargo tank side of the connection. A notice is to be provided located in a prominent position adjacent to the means of isolation, clearly indicating that the spool piece is to be removed and blanking flanges are to be fitted, when the inert gas system is not in use. The removable spool piece is to be clearly identified (labelled/painted in a distinctive colour) and stowed close to its working position.

9.2.8 At least two non-return devices, one of which shall be a water seal, shall be fitted in the inert gas supply main or in the inert gas discharge connection to the vapour return system as applicable, in order to prevent the return of hydrocarbon vapour to any gas-safe spaces under all normal conditions of trim and list. They shall be located between the automatic delivery valve fitted to the forward bulkhead of the forward most gas-safe space and the aftermost connection to any cargo tank.

9.2.9 If a water seal, as required by *Pt 5, Ch 13, 9.2 Type C tankers and Type N-closed tankers 9.2.8*, is impracticable, it may be substituted by a double block and bleed system. Details of this system are to be submitted for approval.

9.3 Type G tankers

9.3.1 The inert gases should be compatible chemically and operationally, at all temperatures likely to occur within the spaces to be inerted, with the materials of construction of the cargo.

9.3.2 Where inert gas is also stored for fire-fighting purposes, it should be carried in separate containers and should not be used for cargo services.

9.3.3 Arrangements suitable for the cargo carried should be provided to prevent the backflow of cargo vapour into the inert gas system.

9.3.4 The arrangements should be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. should be provided for controlling pressure in these spaces.

9.3.5 Inert gas systems are to be so designed as to minimise the risk of ignition from the generation of static electricity by the system itself.

9.3.6 The equipment should be capable of producing inert gas with an oxygen content at no time greater than 5 per cent by volume. A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 5 per cent oxygen content by volume. The above is subject to the special requirements of Table C of Part 3 of the ADN where a lower maximum oxygen content may be specified for specific cargoes (*see Pt 5, Ch 13, 1.3 Materials 1.3.9* for reference).

9.3.7 An inert gas system should have pressure controls and monitoring arrangements appropriate to the cargo containment system. Acceptable means, located in the cargo area, of preventing the backflow of cargo gas should be provided.

9.3.8 If the inert gas plants are located in machinery spaces or other spaces outside the cargo area, two nonreturn valves, or equivalent devices should be fitted in the inert gas main in the cargo area as required in *Pt 5, Ch 13, 9.3 Type G tankers 9.3.7*.

■ *Section 1* General

1.1 Scope

1.1.1 The requirements of this Chapter apply to the welding of pressure vessels and pressure pipes. The allocation of Class is determined from the design criteria referenced in *Pt 5, Ch 8 Fired Boilers*, *Pt 5, Ch 9 Pressure Vessels other than Boilers* and *Pt 5, Ch 10 Piping Design Requirements*.

1.1.2 Fusion welded pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding required for the Class of vessel proposed. For independent tanks intended for Type G tankers or pressure vessels containing LNG for propulsion purposes, the Manufacturer's works are to be assessed and approved *see Pt 5, Ch 14, 2.1 General requirements 2.1.3*.

1.1.3 For pressure vessels which only have circumferential seams, *see Pt 5, Ch 9, 1.5 Classification of fusion welded pressure vessels 1.5.5*.

1.1.4 Requirements for fusion welding of pressure vessels and piping of other recognised Codes or standards, giving an equivalent level of quality, can be accepted.

1.2 General requirements for welding plant and welding quality

1.2.1 In the first instance, and before work is commenced, the Surveyors are to be satisfied that the required quality of welding is attainable with the proposed welding plant, equipment and procedures reference is made to the *Materials and Qualification Procedures for Ships*, Book A, Procedure 0-4.

1.2.2 All welding is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.3 Manufacture and workmanship of fusion welded pressure vessels

1.3.1 Pressure vessels are to be constructed and examined in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials, unless more stringent requirements are specified.

■ *Section 2* Manufacture and workmanship of fusion welded pressure vessels

2.1 General requirements

2.1.1 Prior to commencing construction, the design of the vessel is to be approved, where required, by *Pt 5, Ch 8, 1.2 Plans* and *Pt 5, Ch 9, 1.6 Plans*.

2.1.2 Pressure vessels will be accepted only if manufactured by firms that have been assessed and approved as indicated in *Pt 5, Ch 14, 2.1 General requirements 2.1.3* .

2.1.3 Class 1 and Class 2/1 fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake the quality welding required for the Class of vessels proposed. In order that firms may be approved for this purpose, it will be necessary for the Surveyor to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests as referred to in *Pt 5, Ch 14, 2.1 General requirements 2.1.8*. For Class 1 independent cargo tanks on Type G tankers or for pressure vessels containing LNG for propulsion purposes, the Manufacturer's works are to be assessed and approved in accordance with the *Materials and Qualification Procedures for Ships, Book A Procedure MQPS 0-4, "Approval of works for the Manufacture of Fusion Welded Pressure Vessels* ".

2.1.4 Class 2/2 pressure vessels made in accordance with Class 2/2 requirements, will be accepted only if constructed by firms whose works are properly equipped to undertake the welding of pressure vessels of this Class.

2.1.5 It will be necessary for the Surveyor to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests as referred to in *Pt 5, Ch 14, 2.1 General requirements 2.1.8*.

2.1.6 Class 3 pressure vessels will be accepted if constructed by firms whose works are equipped to undertake the welding of pressure vessels of this Class.

2.1.7 It will be necessary for the Surveyor to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests to demonstrate the quality of the welding. These tests are to be carried out by the firm under the supervision of the Surveyor. The test requirements will be based on the welding process used, but are to be similar to those described in *Ch 13, 4.8 Mechanical requirements 4.8.4* and *Ch 13, 4.8 Mechanical requirements 4.8.5* of the Rules for Materials.

2.1.8 For preliminary tests, *see* the *Materials and Qualification Procedures for Ships*, Book A, MQPS 0-4, Section 4.1.

2.2 Materials of construction

2.2.1 Where the construction requires post-weld heat treatment, consideration should be given to certifying the material after subjecting the test pieces to a simulated heat treatment.

2.3 Tolerances for cylindrical shells

2.3.1 Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

2.3.2 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in *Table 14.2.1 Tolerances for cylindrical shells*.

Table 14.2.1 Tolerances for cylindrical shells

Nominal internal diameter of vessel in mm	Difference between maximum and minimum diameters	Maximum departure from designed form
≤ 300	1% of internal diameter	1,2 mm
> 300 ≤ 460		1,6 mm
> 460 ≤ 600		2,4 mm
> 600 ≤ 900		3,2 mm
> 900 ≤ 1200		4,0 mm
> 1220 ≤ 1520		4,8 mm
> 1520 ≤ 1900		5,6 mm
> 1900 ≤ 2300	19 mm	6,4 mm
> 2300 ≤ 2670		7,2 mm
> 2670 ≤ 3950		8,0 mm

> 3950 ≤ 4650 > 4650	19 mm 0,4% of internal diameter	0,2% of internal diameter

2.3.3 The profile measured on the inside or outside of the shell, by means of a gauge of the designed form of the shell, and having a chord length equal to one-quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in *Table 14.2.1 Tolerances for cylindrical shells*. This amount corresponds to *x* in*Figure 14.2.1 Tolerances for cylindrical shells*.

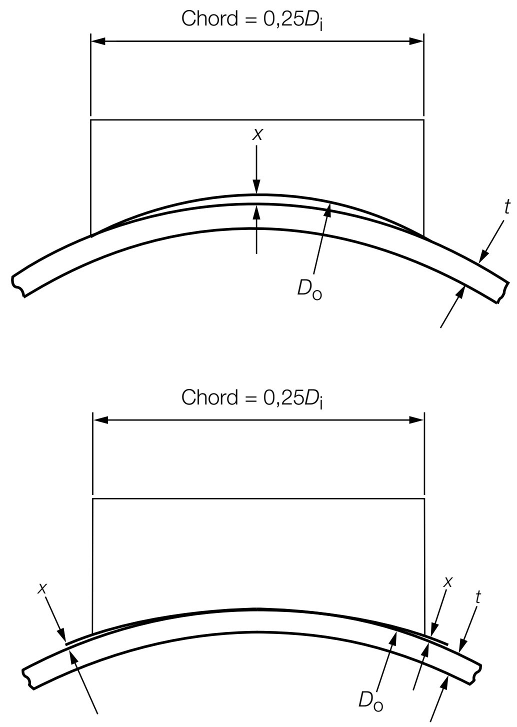


Figure 14.2.1 Tolerances for cylindrical shells

2.3.4 Shell sections are to be measured for out-ofroundness, either when laid flat on their sides or when set up on end. When the shell sections are checked while lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged, and the amount of out-of-roundness calculated from the average values so determined.

2.3.5 Where there is any local departure from circularity due to the presence of flats or peaks at welded seams, the departure from designed form shall not exceed that of *Table 14.2.1 Tolerances for cylindrical shells*.

2.3.6 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the amounts given in *Table 14.2.2 Circumferential tolerances*.

Table 14.2.2 Circumferential tolerances

Outside diameter (nominal inside diameter plus twice actual plate thicknes), in mm	Circumferential tolerance

300 to 600 inclusive	±5 mm
Greater than 600	±0,25 per cent

Section 3
Repairs to welds on fusion welded pressure vessels

3.1 General

3.1.1 Repairs to welds on fusion welded pressure vessels are to be in accordance with the requirements of *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

Section 4
Post-weld heat treatment of pressure vessels

4.1 General

4.1.1 Post-welded heat treatment of fusion welded pressure vessels are to be in accordance with the requirements of *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

Section 5
Welded pressure pipes

5.1 General

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of *Ch 13, 5 Specific requirements for pressure piping* of the Rules for Materials.

5.2 Welding workmanship

5.2.1 Preheating is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

5.2.2 All welding is to be performed in accordance with the approved welding procedures, *see* 5.3.1, by welders who are qualified for the materials, joint types and welding processes employed.

5.2.3 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.4 All welds in high pressure and high temperature pipelines are to have a smooth surface finish and even contour; if necessary, they are to be made smooth by grinding.

5.2.5 Check tests of the quality of the welding are to be carried out periodically at the discretion of the Surveyors.

Section 6
Non-Destructive Examination

6.1 General

6.1.1 Non- Destructive Examination (NDE) of pressure vessels and piping is to be performed in accordance with the requirements of *Ch 1 General Requirements* and *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of steering systems.

1.1.2 The requirements of this Chapter are based on the assumption of heavy traffic on relatively narrow waterways through densely populated areas. When ships are intended to be used on waterways with service conditions different from this, they will receive special consideration.

1.1.3 Attention is also drawn to additional requirements of National or International Authorities, e.g. the Rules issued by the Central Rhine Commission.

1.1.4 Consideration will be given to other cases, or to arrangements which are equivalent to those required by the Rules.

Cross-references

For azimuth or rotatable thruster units, *see Pt 5, Ch 16 Azimuth Thrusters*.

For bow thruster units intended for manoeuvring, *see Pt 5, Ch 17 Steerable Bow Thrusters*.

For general piping requirements, *see Pt 5, Ch 10 Piping Design Requirements*, *Pt 5, Ch 11 Ship Piping Systems* and *Pt 5, Ch 12 Machinery Piping Systems*.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the wheel house to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudderstock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.2.3 **Steering gear power unit** means:

(a) In the case of electric steering gear, an electric motor and its associated electrical equipment;
(b) In the case of electro hydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;
(c) In the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering** gear means the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the ship is designed to maintain, at maximum loaded draught, at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which converts directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with *Pt 5, Ch 15, 2.1 General 2.1.2*.

1.2.9 **Steering arrangements** means the complete system of components for providing ship directional control.

1.2.10 **Directional control system**means the equipment used to effect changes in ship direction, e.g. the rudder, podded propulsion unit, azimuth thrusters or water jet nozzle. Note that, for podded propulsion systems, azimuth thrusters, water jet systems, or other similar systems for effecting changes in ship direction, it is to be assumed that the units must provide thrust in addition to rotation and hence the directional control system must include the propulsion system.

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

1.4 Plans

1.4.1 Before starting construction, the steering gear machinery plans, specifications and calculations are to be submitted. The plans are to give:

(a) Details of scantlings and materials of all load bearing and torque transmitting components and hydraulic pressure retaining parts together with proposed rated torque and all relief valve settings.
(b) Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.
(c) Details of control and electrical aspects.

1.5 Materials

1.5.1 All the components used in steering arrangements for ship directional control are to be manufactured in accordance with the Rules for Materials.

1.5.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* .

1.5.3 All steering unit components transmitting mechanical forces are to be of steel or other approved ductile material. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for low pressure valve bodies and mechanical parts with low stress levels.

1.5.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

1.6 Rudder, rudder stock, tiller and quadrant

1.6.1 For the requirements of rudder and rudder stock, *see Pt 3, Ch 12, 2 Rudders*.

1.6.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see Table 15.1.1 Connection of tiller to stock*.

Table 15.1.1 Connection of tiller to stock

Item	Requirements
(1) Dry fit – tiller to stock, *see also Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.5* and *Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.6*	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock, *see also Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.5*and *Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.6*	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit-tiller to stock, *see also Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.5*	(a) Factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2
(4) Bolted tiller and quadrant	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: $t_s = 0{,}0014\delta_{su}$ mm For 6 connecting bolts: $t_s = 0{,}0012\delta_{su}$ mm Key(s) to be fitted Diameter of bolts, $d_{tb} = \frac{0,60\,\delta_{su}}{\sqrt{n_{tb}}}$ mm A predetermined setting-up load equivalent to a stress of a proximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted. Distance from centre of stock to centre of bolts should generally be equal to $\delta_{su}\left(1,0 + \frac{0,3}{\sqrt{n_{tb}}}\right)$ mm Thickness of flange on each half of the bolted tiller ≥ $\frac{0,66\,\delta_{su}}{\sqrt{n_{tb}}}$ mm
(5) Key/keyway	Effective sectional area of key in shear ≥ $0{,}25\delta_{su}{}^2$ mm^2 Key thickness ≥ $0{,}17\delta_{su}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress

(6) Section modulus – tiller arm (at any point within its length about vertical axis)	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0,21\,\delta^3_{su}\left(b_T - b_s\right)}{1000 b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0,083\,\delta^3_{su}\left(b_T - 0,9b_s\right)}{1000 b_T}$ cm^3 If more than one arm fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 4
(7) Boss	Depth of boss ≥ δ_{su} mm Thickness of boss in way of tiller, irrespective of the keyway: ≥ 0,4δ_{su} mm

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm

= NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm

n_{tb} = number of bolts in the connection flanges, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

δ_{su} = rule rudderstock diameter in way of tiller, *see Table 12.2.1 Rudder stock diameter* in Pt 3, Ch 12

= The rudderstock diameter obtained from *Table 12.2.1 Rudder stock diameter* in Pt 3, Ch 12 is based on the specified material properties of the rudder stock. An equivalent rudder stock diameter δ_e may be applied for components having a different material from the rudder stock material. This equivalent diameter may be determined as follows:-

$$\delta_e = \delta_{su}\left(\frac{\sigma_o}{\sigma_{oc}}\right)^{0,25}$$

where

= σ_o = the yield stress of the rudder stock material

= σ_{oc} = the yield stress of the component material

= Both stresses are to be taken not greater than 70 % of the ultimate tensile strength or 450 N/mm^2, whichever is lesser. As a minimum, the stresses are to be not less than 200 N/mm^2

d_{tb} = diameter of bolts securing bolted tillers and quadrants, in mm

1.6.3 An efficient locking or brake arrangement is to be fitted to all gears to keep the rudder steady when necessary. In the case of hydraulic steering gears which are fitted with isolating valves on the body of the gear and duplicate power units, an additional mechanical brake need not be fitted.

1.6.4 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

1.6.5 The factor of safety against slippage, S (i.e. for torque transmission by friction) is generally based on

$$S = \frac{\text{The torque transmissable by friction}}{M}$$

where M is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

1.6.6 For conical sections, S is based on the following equation:

$$S = \frac{\mu A \sigma_{\mathrm{r}}}{\sqrt{\left(W + A \sigma_{\mathrm{r}} \theta\right)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2

W = weight of rudder and stock, if applicable, when tending to separate the fit, in N

Q = shear force = $\frac{2M}{d_{\mathrm{m}}}$ in N

d_{m} = in mm, is the mean contact diameter of tiller/stock interface and M, in N/mm, is defined in *Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.5*

θ = cone taper half angle in radians (e.g. for cone taper 1:10, Q = 0,05)

μ = coefficient of friction

σ_r = radial interfacial pressure or grip stress, in N/mm^2.

1.6.7 On double rudder installations, where the two tillers are connected by mechanical means (tie-bar), the strength and stability of the tie-bar is to be assessed using the maximum steering torque applied to the stock.

1.6.8 Where higher tensile steel bolts are used on bolted tillers and quadrants, the yield and ultimate tensile stresses of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required setting-up stress. Where proprietary nuts or systems are used, the manufacturer's instructions for assembly are to be adhered to.

■ *Section 2* Performance

2.1 General

2.1.1 Unless the main steering arrangements for ship directional control comprise two or more identical power units, in accordance with *Pt 5, Ch 15, 2.1 General 2.1.4*, every ship is to be provided with main steering arrangements and auxiliary steering arrangements in accordance with the requirements of the Rules. The main and auxiliary steering arrangements are to be so arranged that the failure of one of them will not render the other one inoperative.

2.1.2 The main steering arrangements for ship directional control are to be:

(a) Of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated in accordance with *Pt 5, Ch 15, 5.2 Trials*;
(b) The parts comprising the steering arrangements for ship directional control are to be so dimensioned that they can withstand all the maximum stresses to which they will be subjected in normal operating conditions. The steering arrangements for ship directional control are to be sufficiently strong to withstand abnormal forces (e.g. when the rudder is touching bottom or a bank), the maximum possible damage in such cases being limited to deformation or fracturing of the rudder or stock.
(c) The steering arrangements for ship directional control are to be so designed that a rudder angle of not less than 35° on either side can be obtained. On ships where, due to operation in restricted waters or the passage of locks, a higher degree of manoeuvrability is required, this angle is to be suitably increased;
(d) Where the steering arrangements for ship directional control are manually operated, one complete turn of the hand wheel is to correspond to at least 3° of rudder angle;

(e) Where the steering arrangements for ship directional control are power driven, they are to be capable of turning the rudder at an average rate of 4° per second through the entire rudder arc when the rudder is fully immersed and with the ship at maximum ahead service speed.

2.1.3 The auxiliary steering arrangements for ship directional control are to be:

(a) Of adequate strength and capable of steering the ship at a speed of not less than 13 km/h and of being brought speedily into action in an emergency;
(b) The steering arrangements for ship directional control are to be so designed that a rudder angle of not less than 35° on either side can be obtained. On ships where, due to operation in restricted waters or the passage of locks, a higher degree of manoeuvrability is required, this angle is to be suitably increased;
(c) The steering arrangements for ship directional control and their source of power are to be designed for an operation of not less than 30 minutes and to permit the ship to proceed to a mooring;
(d) Where the steering arrangements for ship directional control are manually operated, one complete turn of the hand wheel is to correspond to at least 3° of rudder angle;
(e) Where the steering arrangements for ship directional control are power driven, they are to be capable of turning the rudder at an average rate of 4° per second through the entire rudder arc when the rudder is fully immersed, and with the ship at a speed of not less than 13 km/h.

2.1.4 Where the main steering arrangements for ship directional control comprise two or more identical power units, an auxiliary steering gear need not be fitted, provided that:

(a) In a passenger ship, the main steering arrangements for ship directional control are capable of operating the rudder as required by *Pt 5, Ch 15, 2.1 General 2.1.2.(c)* and *Pt 5, Ch 15, 2.1 General 2.1.2.(e)* while any one of the power units is out of operation;
(b) In a cargo ship, the main steering arrangements for ship directional control are capable of operating the rudder as required by*Pt 5, Ch 15, 2.1 General 2.1.2.(c)* and *Pt 5, Ch 15, 2.1 General 2.1.2.(e)* while operating with all power units;
(c) The main steering arrangements for ship directional control are arranged so that after a single failure in its piping system or in one of the power units the defect can be isolated so that steering capability can be maintained or speedily regained.

2.1.5 Power units of main and auxiliary steering arrangements for ship directional control are to be:

(a) Arranged to re-start immediately by manual initiation;
(b) Capable of being brought into operation from a position on the wheelhouse. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given on the wheelhouse;
(c) Arranged so that transfer between units can be readily effected.

2.1.6 Steering arrangements for ship directional control, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

2.1.7 Manually operated arrangements for ship directional control are only acceptable when the operation does not require an effort exceeding 160 N under normal conditions.

2.2 Rudder angle limiters

2.2.1 Power driven steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control. Limit switches may be omitted for steering gear having rudder angles exceeding 45° each side.

■ *Section 3* Construction and design

3.1 General

3.1.1 The entire steering gear is to be designed, constructed and installed to allow for a permanent transverse list of up to 15° and for ambient temperatures commensurate with the area in which the ship is to operate.

3.1.2 Rudder actuators are to be designed in accordance with the relevant requirements of *Pt 5, Ch 9 Pressure Vessels other than Boilers* for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.3 Accumulators, if fitted, are to comply with the relevant requirements of *Pt 5, Ch 9 Pressure Vessels other than Boilers*.

3.1.4 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

3.1.5 The construction is to be such as to minimise local concentrations of stress.

3.1.6 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure taking into account any pressure which may exist in the low pressure side of the system.

3.1.7 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \quad \text{or} \quad \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

= *A* and *B* are given by *Table 15.3.1 Material factors of safety*.

Table 15.3.1 Material factors of safety

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

3.1.8 No other consumers may be connected to the hydraulic steering gear drive unit.

3.2 Components

3.2.1 Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

3.2.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

3.2.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

3.2.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be such that the failure of one seal does not render the actuator inoperative.

3.2.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Chapter 10 for Class I piping systems components. The design pressure is to be in accordance with*Pt 5, Ch 15, 3.1 General 3.1.6*.

3.2.6 Hydraulic power operated steering gears are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

3.3 Valve and relief valve arrangements

3.3.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

3.3.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

3.3.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves are not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.3.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by *Pt 5, Ch 15, 3.3 Valve and relief valve arrangements 3.3.3*, are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.
(b) The minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them). Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

3.4 Flexible hoses

3.4.1 Hose assemblies approved by Lloyd's Register may be installed between two points where flexibility is required. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery, *see Pt 5, Ch 10, 8 Hydraulic tests on pipes and fittings* for the applicable requirements.

3.4.2 The service lifetime of the flexible hoses for the steering gear is not to exceed the Manufacturer’s recommendations. In all cases the hoses are to be replaced after 10 years of service.

■ *Section 4*
Steering control and electric power systems

4.1 Fully powered steering gear

4.1.1 Fully powered steering gears may be of the direct electric or electric/hydraulic type; requirements for the electric and control engineering, *see also Pt 6, Ch 1, 3.7 Steering gear* and *Pt 6, Ch 2, 2.8 Steering gear*.

4.1.2 Powered steering gears are to be fitted with means to limit the torque exerted by the drive.

4.1.3 In case of failure of the main drive and the secondary drive not engaging automatically, it is to be possible to engage the secondary drive by hand at the steering position within five seconds, with the rudder in any position.

4.1.4 At the steering station, automatic indication is to be provided as to which drive is in operation.

4.1.5 If the independent secondary drive is manual the power drive is not to actuate the hand wheel. A device is to be fitted to prevent inadvertent turning of the hand wheel when the manual drive is engaged automatically.

4.1.6 Where the main steering gear is power operated whilst the secondary steering is a manually operated hydraulic system, the piping of both systems is to be completely separate, and the main installation is to operate without using the steering wheel pump of the secondary installation.

4.1.7 Where both the main and secondary drive is power hydraulic, the respective pumps are to be driven independently.

4.1.8 Where the secondary pump is driven by an engine which does not operate continuously whilst the ship is in motion, means are to be provided to operate the steering gear instantly whilst the emergency engine is gaining the required speed.

4.1.9 The two installations are to have separate pipes, valves, controls, etc. Where the independent functioning of the two installations is ensured, they may have common components.

4.1.10 Where the steering gear is so arranged that more than one power system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

4.2 Manual drive

4.2.1 Where the sole steering installation is a manually operated system, an independent secondary steering system is not required, provided that in the case of a hydraulic system the dimensioning, construction and layout of the piping precludes deterioration through mechanical action or fire, and the construction of the steering wheel pump ensures faultless operation.

4.2.2 A manually operated steering gear may be supplemented by a power assistance installation provided the steering assistance gear is capable of being engaged or disengaged at the steering station with the rudder in any position and the ‘on’ position is clearly indicated.

4.2.3 If a power assisted manual drive is fitted as a secondary means of steering, the power assistance installation is to be completely separate from the main steering system and is not to preclude compliance with *Pt 5, Ch 15, 4.1 Fully powered steering gear 4.1.3*.

4.3 Rudder position

4.3.1 If the position of the rudder(s) is not clearly discernable from the steering station, a reliable rudder angle indicator is to be provided at the steering station.

4.3.2 Any rudder angle indicator fitted, is to function for both the main and secondary steering gear.

■ *Section 5* Testing and trials

5.1 Testing

5.1.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping, and related fittings including hydraulic testing, apply.

5.1.2 After installation on board the vessel the steering gear is to be subjected to the required hydrostatic and running tests.

5.1.3 Each type of power unit pump is to be subjected to a type test. The type tests may be waived for a power unit which has been proven to be reliable in marine service.

5.2 Trials

5.2.1 The steering gear is to be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering gear, including demonstration of the performances required by *Pt 5, Ch 15, 2.1 General 2.1.2.(d)* and*Pt 5, Ch 15, 2.1 General 2.1.2.(e)* and *Pt 5, Ch 15, 2.1 General 2.1.3.(d)* and *Pt 5, Ch 15, 2.1 General 2.1.3.(e)*:

- For the main steering gear trial, the propeller pitch of controllable pitch propellers is to be at the maximum design pitch approved for the maximum continuous ahead RPM;
- During navigation tests ships other than passenger ships shall be loaded to at least 70 per cent of their tonnage and loading, Passenger ships are to be tested at their deepest draught. If a ship cannot be tested under the above stipulations alternative trial conditions may be specially considered. In this case, for the main steering gear trial, the speed of the ship corresponding to the maximum continuous revolutions of the main engine should apply.

(b) The steering gear power units, including transfer between steering gear power units;
(c) The isolation of one power actuating system, checking the time for regaining steering capability;
(d) The operation of the auxiliary steering gear as required by*Pt 5, Ch 15, 2.1 General 2.1.3.(c)*;
(e) The steering gear controls, including transfer of control and local control;
(f) The alarms and indicators;
(g) Where the steering gear is designed to avoid hydraulic locking, this feature shall be demonstrated.

Test items *Pt 5, Ch 15, 5.2 Trials 5.2.1.(f)* and *Pt 5, Ch 15, 5.2 Trials 5.2.1.(g)* may be effected at the dockside.

5.2.2 The ability of the machinery to reverse the direction of propeller thrust in sufficient time and bring the ship to rest within a reasonable distance from maximum ahead service speed is to be demonstrated and recorded.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter applies to azimuth or rotatable thruster units for propulsion, which transmit a power greater than 220 kW used as the sole means of steering, and are in addition to the relevant requirements of *Pt 5, Ch 15 Steering Systems*.

1.1.2 Azimuth or rotatable thruster units for propulsion where the power exceeds 2000 kW are to comply with the relevant requirements of the *Rules and Regulations for the Classification of Ships, July 2022* (hereinafter referred to as Rules for Ships).

1.1.3 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion.

1.1.4 The failure of one azimuth thruster unit or its control system is not to render any other thrusters inoperative.

1.2 Plans

1.2.1 The following additional plans are to be submitted for consideration together with particulars of materials and the maximum shaft power and revolutions per minute:

- Sectional assembly including nozzle ring structure, nozzle support struts, etc.
- Shafts, gears and couplings.
- Steering mechanisms with details of ratings.
- Bearing specifications.
- Schematic piping systems of lubricating and hydraulic systems together with pipe material, relief valves and working pressures.

1.3 Condition Monitoring

1.3.1 Where Thruster Condition Monitoring (ThCM) ShipRight descriptive note has been requested, refer to *ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring*, Section 8.

1.4 *Cross-references*

1.4.1 For strengthening for Navigation in Ice, *see Pt 5, Ch 7 Strengthening for Navigation in Ice*.

For general piping requirements, *see Pt 5, Ch 10 Piping Design Requirements*, *Pt 5, Ch 11 Ship Piping Systems* and *Pt 5, Ch 12 Machinery Piping Systems*.

For steering gear, *see Pt 5, Ch 15 Steering Systems*.

■ Section 2
Performance

2.1 General

2.1.1 The arrangement of thrusters is to be such that the ship can be satisfactorily manoeuvred with both thrusters simultaneously as well as with a single thruster and is to be demonstrated during trials to an accepted trials programme.

2.1.2 For vessels with multiple azimuthing thrusters, the requirement for auxiliary steering arrangements in *Pt 5, Ch 15, 2 Performance* is to be achieved by equipping each of the azimuthing thrusters with its own dedicated and independent steering gear control system and power actuating system. Consideration will be given to alternative arrangements providing equivalence can be demonstrated.

2.1.3 In addition to the requirements of *Pt 5, Ch 15 Steering Systems*, the azimuthing mechanism is to be capable of a rotational speed of not less than 1,5 rev/min.

2.1.4 The steering arrangements are to be capable of changing the direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,4 rev/min, with the ship running ahead at maximum ahead service speed.

■ Section 3
Construction and design

3.1 Materials

3.1.1 Specification for materials of gears, shafts, couplings and propeller, giving chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.1.2 Specification for materials for the stock, struts, etc. are to be submitted for approval.

3.1.3 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in *Pt 5, Ch 7 Strengthening for Navigation in Ice* and *Pt 3, Ch 9, 3 Strengthening for navigation in ice*.

3.2 Design

3.2.1 For steerable thrusters with or without nozzle, the stresses in the nozzle stock or steering pipe are to be determined as follows:

$$\sigma_B = \frac{M_B}{Z_B}$$

$$\tau_T = \frac{M_T}{Z_T}$$

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau_T^2}$$

where

σ_B = bending stress, in N/mm^2

M_B = bending moment at any section x-x, in Nmm and is to be determined as follows:

= $M_B = 10^6\, T_M\, a$

where

T_M = maximum thrust of the thruster unit, in kN

a = dimension from centreline propeller to plane of consideration, in metres, as shown in *Figure 16.3.1 Steerable thruster*

Z_B = section modulus against bending, in mm^3

τ_T = torsional stress, in N/mm^2

M_T = the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer, in Nmm

Z_T = section modulus against torsion, in mm^3

σ_E = equivalent stress in N/mm^2.

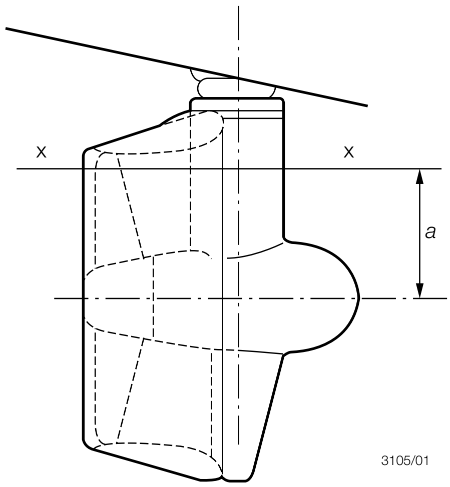


Figure 16.3.1 Steerable thruster

3.2.2 **Permissible stresses:**

- Torsional stress $\tau_T = \frac{68}{k_0}$ N/mm^2
- Equivalent stress $\sigma_E = \frac{118}{k_0}$ N/mm^2

where

k_o is a material factor as in *Table 16.3.1 Material factor*.

For all items calculated, a material factor, k_o, may be used if the material has a better quality than regular carbon steel.

Table 16.3.1 Material factor

σ_o	$k_o/k_b/k_s$
For $\sigma_o > 235$	$\left(\frac{235}{\sigma_0}\right)^{0,75}$
For $\sigma_o \leq 235$	$\left(\frac{235}{\sigma_0}\right)$

Symbols
σ_o = minimum yield stress in N/mm^2 k_o = higher steel correction factor k_b = coupling bolt material factor k_s = rudderstock or steering pipe flange material factor
Note 1. σ_o is to be taken not greater than 70 % of the ultimate tensile strength or 450 N/mm^2, whichever is the lesser. **Note** 2. For bolts, σ_o may be taken not greater than 70 per cent whichever is the lesser.

3.2.3 For coupling bolts, steering pipe/underwater gearbox the requirements of *Pt 5, Ch 16, 3.2 Design 3.2.4* and *Pt 5, Ch 16, 3.2 Design 3.2.5*apply.

3.2.4 **Tap bolts or bolts in clearance holes:**

The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of connecting flanges, pretensioned to 70 per cent of the bolt material yield strength value, is to be not less than:

$$\delta_b = 1{,}348\sqrt{\left(\frac{10\,\pi\,M_T}{d_c}\right)\frac{1}{n\,\sigma_y}}$$

where

M_T = maximum turning moment, in Nmm, *see also Pt 5, Ch 16, 3.2 Design 3.2.1*

n = number of bolts

σ_y = bolt material yield stress, in N/mm^2

d_c = pitch circle of the bolts, in mm.

3.2.5 Fitted bolts will be specially considered.

3.2.6 The minimum thickness, t_f, in mm of the coupling flange:

$$t_f = \delta_b\sqrt{\frac{k_b}{k_s}}$$

where

δ_b = diameter of the coupling bolts, in mm

k_b and k_s are as defined in *Table 16.3.1 Material factor*.

The thickness of the coupling flange is in no case to be less than the actual diameter of the coupling bolts.

3.2.7 The fillet radius at the base of the connecting flange of the steering pipe is to be not less than 0,06 of the diameter of the steering pipe at the flange. A smaller fillet radius can be accepted based on a suitable calculation method in which the effects of stress concentration are to be taken into account.

3.2.8 The nozzle structure is to be in accordance with *Pt 3, Ch 12, 3 Fixed and steering nozzles*.

3.2.9 As an alternative to this Chapter, azimuth thrusters in full compliance with *Pt 5, Ch 20 Azimuth Thrusters*of the Rules for Ships are also acceptable for Inland Waterways Rules applications.

3.3 Steering gear elements

3.3.1 These gears are to be considered for the following conditions:

- a design maximum dynamic duty steering torque;
- a static duty (≤10^3 load cycles) steering torque, and the static duty steering torque should be not less than M_T.

Values for the above should be submitted together with the plans.

3.4 Components

3.4.1 The hydraulic power operating systems for each azimuth thruster are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

3.4.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil.

3.4.3 For flexible hoses, reference is made to *Pt 5, Ch 10, 7 Flexible hoses*.

3.5 Locking of thruster unit

3.5.1 Azimuth propulsion systems are to be capable of being locked in a fixed position, *see also Pt 5, Ch 15, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.3*.

3.6 Prime movers

3.6.1 Engines intended for driving thrusters are to comply with the applicable requirements of *Pt 5, Ch 2 Engines*.

3.7 Gears

3.7.1 The gears are to be in compliance with the applicable requirements of *Pt 5, Ch 3 Gearing* with an application factor K_A in *Table 3.3.1 Values of K_A* and a factor of safety for contact stress and bending as intended for multiple screw applications, see *Table 3.3.4 Factors of safety*. As an alternative to *Pt 5, Ch 3 Gearing*, gear elements may be designed in accordance with ISO 6336, Parts 1, 2, 3 and 5.

3.8 Shafts

3.8.1 The diameter of screw shaft is to be not less than required by *Pt 5, Ch 4, 3 Design*.

3.8.2 Torsional vibration characteristics of the shaft system are to be in compliance with *Pt 5, Ch 6 Shaft Vibration and Alignment*.

3.8.3 Calculations of the lateral vibration characteristics of shafting systems incorporating cardan shafts are to be submitted in accordance with *Pt 5, Ch 6 Shaft Vibration and Alignment*.

3.9 Propellers

3.9.1 Propellers are to be in compliance with the requirements of *Pt 5, Ch 5 Propellers*.

■ *Section 4*
Control engineering arrangements

4.1 General

4.1.1 Except where indicated in this Section, the control engineering systems are to be in accordance with *Pt 6, Ch 1 Control Engineering Systems*.

4.1.2 Steering control is to be provided for the azimuth thrusters from the wheelhouse.

4.1.3 An indication of the angular position of the thrusters and the magnitude of the thrust are to be provided at the wheelhouse from which it is possible to control the direction of thrust.

4.1.4 Means are to be provided to stop each thrust unit locally and at the wheelhouse.

4.2 Monitoring and alarms

4.2.1 Alarms and monitoring requirements are indicated in*Pt 5, Ch 16, 4.2 Monitoring and alarms 4.2.2*and *Table 16.4.1 Alarms for control systems*.

Table 16.4.1 Alarms for control systems

Item	Alarm	Note
Thruster azimuth	—	Indicator, *see Pt 5, Ch 16, 4.1 General 4.1.3*
Steering motor	Power failure, single phase	Also running indication at wheelhouse
Propulsion motor	Power failure	Also running indication at wheelhouse
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply	Low	If separate forced lubrication

4.2.2 The alarms described in *Table 16.4.1 Alarms for control systems* are to be indicated individually on the wheelhouse and in accordance with the alarm system specified by *Pt 6, Ch 1, 2.3 Alarm systems*.

■ *Section 5*
Electrical equipment

5.1 General

5.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of*Pt 5, Ch 16, 5.2 Generating arrangements*.

5.1.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, of *Pt 6, Ch 2 Electrical Installations* are to be complied with.

5.2 Generating arrangements

5.2.1 Where a central power generation system is employed, the requirements of *Pt 6, Ch 2, 2.3 Number and rating of generating sets* are to be complied with.

5.2.2 The generating and distribution system is to be so arranged that after any single failure, steering capability can be maintained or regained immediately, and the effectiveness of the steering after such a fault will not be reduced by more than 50 per cent. This may be achieved by the parallel operation of two or more generating sets, or alternatively when the electrical requirements may be met by one generating set in operation, on loss of power, the automatic starting and connection to the switchboard of a standby set, provided that this set can restart and run a thruster with its auxiliaries.

5.2.3 The failure of one thruster unit or its control system is not to render any other thruster inoperative.

5.2.4 A single failure of generator/switchboard should not lead to failure of any other generator/switchboard.

5.3 Distribution arrangements

5.3.1 Thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

5.4 Auxiliary supplies

5.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:

(a) The voltage regulation and current sharing requirements defined in *Pt 6, Ch 2, 4.5 Alternating current service generators* are to be maintained over the full range of power factors that may occur in service.
(b) Auxiliary equipment and services are to operate with any waveform distortion introduced by converters without deleterious effect (this may be achieved by the provision of suitably filtered/converted supplies).
(c) The thrusters should not influence the other essentials.

■ *Section 6*
Testing and trials

6.1 General

6.1.1 The requirements detailed in *Pt 5, Ch 1 General Requirements for the Design and Construction of Machinery*, *Pt 5, Ch 3 Gearing* and *Pt 5, Ch 15 Steering Systems* are to be complied with and, in addition, the performance specified in*Pt 5, Ch 16, 2.1 General 2.1.3* is to be demonstrated to the Surveyor's satisfaction.

6.1.2 The actual values of steering torque should be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter applies to bow thruster units intended for manoeuvring having a power of 110 kW and over, fitted on ships with a length exceeding 110 m, *see Pt 5, Ch 1, 5 Propulsion redundancy* or where a fire in the main machinery space incapacitates the main engines. *See Pt 5, Ch 1, 4.3 Ventilation 4.3.4*.

1.1.2 Thrusters of less than 110 kW are to be built in accordance with good engineering practice and tested as required in *Pt 5, Ch 17, 6.1 General*.

1.2 Plans

1.2.1 The following plans are to be submitted for consideration, together with particulars of materials and the maximum shaft power and revolutions per minute:

- Sectional assembly.
- Shafts, sealing devices, gears and couplings.
- Steering mechanisms with details of ratings.
- Bearing specifications.
- Schematic piping systems.
- Propeller/impeller where the diameter exceeds 1 m.
- For CPP installations, pitch control device.
- Structure of the tunnel showing details and thicknesses.

1.3 *Cross-references*

1.3.1 For strengthening for Navigation in Ice, *see Pt 5, Ch 7 Strengthening for Navigation in Ice*.

For general piping requirements, *see Pt 5, Ch 10 Piping Design Requirements*, *Pt 5, Ch 11 Ship Piping Systems* and *Pt 5, Ch 12 Machinery Piping Systems*.

For steering gear, *see Pt 5, Ch 15 Steering Systems*.

For azimuth or rotatable thruster units, *see Pt 5, Ch 16 Azimuth Thrusters*.

Section 2
Performance

2.1 General

2.1.1 The arrangement of the bow thruster is to be such that the ship can maintain a speed of not less than 6,5 km/h also in the unloaded condition and can be satisfactorily propelled in accordance with *Pt 5, Ch 1, 5 Propulsion redundancy*. The steering gear of the bow thrust unit is to be provided with two independent means of steering in compliance with *Pt 5, Ch 15, 2.1 General 2.1.1* .

Section 3
Construction and design

3.1 Materials

3.1.1 Specification for materials of gears, shafts, couplings and propeller, giving chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.1.2 Specification for materials for the stock, etc. are to be submitted for approval.

3.1.3 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in *Pt 5, Ch 7 Strengthening for Navigation in Ice* and *Pt 3, Ch 9, 3 Strengthening for navigation in ice*.

3.2 Design

3.2.1 For steerable bow thrusters, the maximum transmitted torque, M_T, is to be the greater of:

- Manufacturers rating.
- Calculated maximum torque generated by steering motor.

3.2.2 The tunnel structure and/or container in which the thrust unit is fitted, is to be in compliance with*Pt 3, Ch 12, 4 Bow and stern thrust unit structure*.

3.3 Steering gear elements

3.3.1 These gears are to be considered for the following conditions:

- A design maximum dynamic duty steering torque;
- A static duty ($\leq 10^3$ load cycles) steering torque to be not less than M_T.

Values for the above should be submitted together with the plans.

3.3.2 The rudderstock diameter is to be not less than:

$$d_r = 3,38 \times \sqrt[3]{\frac{M_T}{\sigma_u}} \text{ mm}$$

where

M_T = maximum transmitted torque, in Nmm

σ_u = ultimate tensile strength of the rudderstock material, in N/mm^2.

3.4 Components

3.4.1 The hydraulic power operating systems for steering the bow thruster are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

3.4.2 Relief valves are to be fitted to any part of the hydraulic system which can be isolated. The settings of the relief valves are not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.4.3 For flexible hoses, reference is made to *Pt 5, Ch 10, 7 Flexible hoses*.

3.5 Prime movers

3.5.1 Diesel engines intended for driving thrusters are to comply with the applicable requirements of *Pt 5, Ch 2 Engines*.

3.6 Gears

3.6.1 The gears are to be in compliance with the applicable requirements of *Pt 5, Ch 3 Gearing* with application factors intended for auxiliary gears.

3.7 Shafts

3.7.1 The diameter of protected screw shafts is to be not less than that required for a screw shaft as per *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.2*, in which 94 as per the formula, may be substituted by 85. For unprotected shafts, *Pt 5, Ch 4, 3.4 Screw shafts and tube shafts 3.4.6* will be applicable.

3.7.2 Torsional vibration characteristics of the shaft system are to be in compliance with*Pt 5, Ch 6 Shaft Vibration and Alignment*for bow thrust units exceeding 500 kW power output.

3.7.3 Calculations of the lateral vibration characteristics of shafting systems incorporating cardan shafts are to be submitted in accordance with *Pt 5, Ch 6 Shaft Vibration and Alignment*.

3.8 Propellers

3.8.1 Propellers intended for manoeuvring as in *Pt 5, Ch 1, 5 Propulsion redundancy* are to be in compliance with the requirements of *Pt 5, Ch 5 Propellers*.

■ *Section 4*
Control engineering arrangements

4.1 General

4.1.1 Except where indicated in this Section, the control engineering systems are to be in accordance with *Pt 6, Ch 1 Control Engineering Systems*.

4.1.2 Steering control is to be provided for the bow thruster unit from the wheelhouse.

4.1.3 An indication of the angular position of the thruster(s) and the magnitude of the thrust are to be provided at the wheelhouse from which it is possible to control the direction of thrust.

4.1.4 Means are to be provided at the wheelhouse to stop the thrust unit.

4.2 Monitoring and alarms

4.2.1 Alarms and monitoring requirements are indicated in *Pt 5, Ch 17, 4.2 Monitoring and alarms 4.2.2* and *Table 17.4.1 Alarms for control systems*.

Table 17.4.1 Alarms for control systems

Item	Alarm	Note
Thruster steerable	—	Indicator, *see Pt 5, Ch 16, 4.1 General 4.1.3*
Steering motor	Power failure, single phase	Also running indication at wheelhouse

Propulsion motor	Power failure	Also running indication at wheelhouse
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply	Low	If separate forced lubrication

4.2.2 The alarms described in *Table 17.4.1 Alarms for control systems* are to be indicated individually on the wheelhouse and in accordance with the alarm system specified by *Pt 6, Ch 1, 2.3 Alarm systems*.

■ *Section 5*
Electrical equipment

5.1 General

5.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of*Pt 5, Ch 16, 5.2 Generating arrangements*.

5.1.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, of *Pt 6, Ch 2 Electrical Installations* are to be complied with.

5.2 Generating arrangments

5.2.1 Where a central power generation system is employed, the requirements of *Pt 6, Ch 2, 2.3 Number and rating of generating sets* are to be complied with. The power generation system for the bow thruster is to be located in the fore ship.

5.2.2 Remote start stop including power generating is to be provided.

5.2.3 The stop of the bow thruster unit is to be independent of direction speed control.

5.3 Distribution arrangements

5.3.1 Thruster auxiliaries and controls are to be served by individual circuits which are to be located in the fore ship.

5.4 Auxiliary supplies

5.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:

(a) The voltage regulation and current sharing requirements defined in *Pt 6, Ch 2, 4.5 Alternating current service generators* are to be maintained over the full range of power factors that may occur in service.
(b) Auxiliary equipment and services are to operate with any waveform distortion introduced by convertors without deleterious effect (this may be achieved by the provision of suitably filtered/converted supplies).
(c) The bow thruster should not influence the other essentials.

Section 6
Testing and trials

6.1 General

6.1.1 The requirements detailed in *Pt 5, Ch 1 General Requirements for the Design and Construction of Machinery*, *Pt 5, Ch 3 Gearing*, *Pt 5, Ch 10 Piping Design Requirements*and *Pt 5, Ch 15 Steering Systems* are to be complied with and, in addition, the performance specified in *Pt 5, Ch 17, 2.1 General 2.1.1* is to be demonstrated to the Surveyor's satisfaction.

6.1.2 The actual values of steering torque should be verified during trials to confirm that the design maximum torque has not been exceeded.

6.1.3 The manufacturer's test certificate for materials for the rotating equipment and steering gear will be accepted in lieu of Lloyd’s Register's (hereinafter referred to as LR) materials certificate provided they are to be produced at a works approved by LR and are tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* .

■ *Section 1* **General**

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of hydraulic systems for raising and lowering of wheelhouses on all types of ships except where otherwise stated.

1.1.2 Special attention is drawn to National and International technical and operational requirements of countries where the ship is registered or operating and which are outside classification as defined in these Rules.

1.1.3 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.1.4 For a general description and definitions of elevating wheelhouse systems, *see Pt 3, Ch 13, 1 General requirements*.

1.2 Plans and particulars

1.2.1 The following plans and particulars are to be submitted for approval:

- Arrangement plan of hydraulic cylinder.
- Detail plans of hydraulic cylinder.
- Plans showing connections of cylinder(s) to wheelhouse and cylinder(s) to ship.
- Diagram of hydraulic system.
- Working and relief pressure of hydraulic system.
- For synchronised telescopic cylinders, the working and relief pressure for each compartment.

1.3 Materials

1.3.1 All the components raising the wheelhouse are to be of sound reliable construction to the Surveyor's satisfaction.

1.3.2 All components transmitting mechanical forces to the wheelhouse are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022* (hereinafter referred to as the Rules for Materials).

1.3.3 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by LR.

1.3.4 The cylinders, hydraulic power piping, valves, flanges and fittings and all components transmitting mechanical forces to the wheelhouse are to be of steel or other approved ductile material, duly tested in accordance with the requirements of the Rules for Materials. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

1.3.5 Materials for cylinders having a design temperature less than 0°C are to be in compliance with the Rules for Materials and Charpy-V testing is to be carried out as per the Rules.

1.3.6 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

Section 2
Pumping and piping

2.1 Hydraulic systems for elevating wheelhouses

2.1.1 For general requirements on hydraulic systems, *see Pt 5, Ch 12, 9 Hydraulic systems*.

2.1.2 Arrangements are to be provided to avoid an uncontrolled lowering of the wheelhouse in case of hose rupture.

2.1.3 An emergency lowering arrangement operable from the wheelhouse is to be provided.

2.1.4 Arrangements are to be provided to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

2.1.5 Stopping of wheelhouse lowering is to be such as to avoid an undue rise in pressure in the hydraulic system above the design pressure. *See also Pt 6, Ch 1, 3.9 Liftable wheelhouse systems 3.9.2*.

2.1.6 For hydraulic test on pipes and fittings, *see Pt 5, Ch 10, 8 Hydraulic tests on pipes and fittings*.

2.2 Hydraulic pumps

2.2.1 A standby hydraulic pump is to be provided for dry cargo ships.

2.2.2 The standby pump is to be connected ready for immediate use.

2.2.3 For over-pressure protection of the pumps, *see Pt 5, Ch 12, 4.2 Relief valves on pumps 4.2.1*.

2.2.4 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

2.3 Flexible hoses for elevating wheelhouse

2.3.1 Hose assemblies approved by Lloyd's Register may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery.

2.3.2 Service life time of flexible hoses is not to exceed Manufacturer's recommendations.

2.3.3 In addition to the above the requirements of *Pt 5, Ch 10, 7 Flexible hoses* are to be complied with as far as they are applicable.

Section 3
Hydraulic cylinder

3.1 Hydraulic cylinder

3.1.1 Hydraulic cylinders are to be designed in accordance with the relevant requirements of *Pt 5, Ch 9 Pressure Vessels other than Boilers* for Class 1 pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.2 Accumulators, if fitted, are to comply with the relevant requirements of *Pt 5, Ch 9 Pressure Vessels other than Boilers*.

3.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

3.1.4 The construction is to be such as to minimize local concentrations of stress.

3.1.5 The design pressure for calculations to determine the scantlings of piping and other components subjected to internal hydraulic pressure shall be at least 1,2 times the maximum working pressure to be expected under normal operating conditions.

3.1.6 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be provided with a single pressure seal plus a wiper seal. Alternative arrangements providing equivalent protection against leakage may be accepted.

3.1.7 The design of synchronised telescopic cylinders is to be such that the working pressure in each compartment shall not exceed the design pressure of that compartment under all conditions of service, otherwise each compartment is to be provided with a safety relief valve discharging to atmospheric pressure.

3.2 Allowable stresses hydraulic cylinder

3.2.1 The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \quad \text{or} \quad \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

= A and B are given by the following table:

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

Contents

Part 6

Section 1
General requirements

1.1 General

1.1.1 This Chapter applies to all ships and is in addition to other relevant Sections of the Rules.

1.1.2 Attention should also be given to any relevant requirements of National, International or Local Authorities which would apply to the ships in service.

1.1.3 This Chapter states requirements for systems of automatic or remote control which may be used for controlling the machinery contained in *Pt 6, Ch 1, 1.2 Plans 1.2.2*. The design and installation of other control equipment is to be such that there is no risk of danger due to failure.

1.1.4 The details of control systems will vary with the type of machinery being controlled and special consideration will be given to each case.

1.2 Plans

1.2.1 Where control systems are applied to essential machinery or equipment as listed in *Pt 6, Ch 1, 1.2 Plans 1.2.2*, plans are to be submitted in triplicate. They are to include or to be accompanied by:

Details of operating medium, i.e. pneumatic, hydraulic or electric, including standby sources of power.

Description and/or block diagram showing method of operation.

Line diagrams of control circuits.

Lists of points monitored.

List of alarm points.

List of control points.

Test facilities provided.

Test schedules.

Location drawings of fire detectors.

List of safety functions and details off any overrides, including consequences of use, *see Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.9*.

1.2.2 Control, alarm and safety systems. Plans are required for the following:

Ballast systems.

Bilge systems.

Cargo pumping systems for tankers.

Controllable pitch propellers.

Electrical generating plant.

Fire detection systems.

Main propelling machinery including essential auxiliaries.

Steam raising plant.

Transverse thrust units.

Steering gear plant.

Inert gas generators.

Thermal fluid heaters.

1.2.3 **Alarm systems.** Details of the overall alarm system linking engine room, wheelhouse and, where applicable, accommodation spaces are to be submitted.

1.2.4 **Programmable electronic systems.** In addition to the documentation required by *Pt 6, Ch 1, 1.2 Plans 1.2.2*, the following is to be submitted:

System requirements specification.

Details of the hardware configuration in the form of a system block diagram, including input/output schedules.

Hardware certification details, *see Pt 6, Ch 1, 2.9 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.9.4*.

Software quality plans, including applicable procedures.

Factory acceptance and sea trial test schedules for hardware and software.

1.2.5 **Control station.** Location and details of control stations are to be submitted, e.g. control panels.

1.2.6 **Standard system.** Where it is intended to employ a system which has been previously approved, plans may not be required to be submitted. The building port, where applicable, and date of the previous approval is to be advised.

1.3 Alarm and control equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems as defined in *Pt 6, Ch 1, 1.2 Plans* are to be surveyed at the manufacturers' works and the inspection and testing is to be to the Surveyor's satisfaction.

1.3.2 Equipment used in control, alarm and safety systems should, whenever practicable, be selected from the *List of Type Approved Control and Electrical Equipment* published by LR. A copy of LR's *Test Requirements for the Type Approval of Control and Electrical Equipment* will be furnished on application.

1.3.3 Assessment of performance parameters, such as accuracy, repeatability, etc. are to be in accordance with an acceptable National or International Standard.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey, and the inspection, testing and installation are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

■ *Section 2*
Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control and alarm systems to the equipment defined in *Pt 6, Ch 1, 1.2 Plans 1.2.2*, the applicable features contained in *Pt 6, Ch 1, 2.2 Control station(s) for machinery*are to be incorporated in the system design.

2.2 Control station(s) for machinery

2.2.1 A system of alarm displays and controls are to be provided which readily ensure identification of faults in the machinery and satisfactory supervision of related equipment.

2.3 Alarm systems

2.3.1 Where an alarm system which will provide warning of faults in the machinery and the safety and control systems is installed, the requirements of *Pt 6, Ch 1, 2.3 Alarm systems 2.3.2* are to be satisfied.

2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control station to advise duty personnel of a fault condition.

2.3.3 Individual alarm channels may be displayed as group alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.4 All alarms are to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms. Alarm indicators are to be red and are to flash when unacknowledged.

2.3.5 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible and visual alarms are again to operate. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.6 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.7 Failure of the power supply to the alarm system is to be indicated.

2.3.8 The alarm system should be designed with selfmonitoring properties. As far as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.9 The alarm system is to be designed as far as practical to function independently of control systems such that a failure or malfunction on these systems will not prevent the alarm from operating.

2.3.10 Disconnection or manual overriding of any part of the alarm system should be clearly indicated.

2.3.11 The alarm system is to be capable of being tested.

2.3.12 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.13 In the wheelhouse, all illumination and lighting of instruments, keyboards and controls are to be adjustable down to zero, except the lighting of alarm indicators and the controls of dimmers which are to remain readable.

2.4 Safety systems – General requirements

2.4.1 Where safety systems are provided, the requirements of *Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.2*are to be satisfied.

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g. by the starting of standby machinery, or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery, or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.3 The safety system required by *Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.2.(c)* is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.4 For safety systems required by *Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.2* and *Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.2.(b)* complete independence from other control systems is not necessary.

2.4.5 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.6 The safety system is to be designed to ‘fail-safe’. The characteristics of the ‘fail-safe’ operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation. Failure of a safety system is to initiate an audible and visual alarm.

2.4.7 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.8 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.9 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. The consequences of overriding a safety system are to be established and documented.

2.4.10 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.11 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.12 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.4.13 As far as practicable, the safety system required by *Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.2.(b)* is to be arranged to effect a rapid reduction in speed or power.

2.5 Control systems

2.5.1 Control systems for machinery operations are to be stable throughout their operating range.

2.5.2 Failure of the power supply to a control system for propulsion machinery and associated systems is to operate an audible and visual alarm. *See Pt 6, Ch 1, 3.5 Remote control for propulsion machinery 3.5.1*, *Pt 6, Ch 1, 3.6 Controllable pitch propellers and transverse thrust units 3.6.4* or *Pt 6, Ch 1, 3.7 Steering gear 3.7.5*, as applicable.

2.5.3 When remote or automatic controls are provided, sufficient instrumentation is to be fitted at the relevant control stations to ensure effective control and indicate that the system is functioning correctly.

2.5.4 Where valves are operated by remote or automatic control, the system of control should include the following safety features:

(a) Failure of actuator power should not permit a closed valve to open inadvertently.
(b) Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed. Valve position indicating systems are to be of an approved type.
(c) Equipment located in places which may be flooded should be capable of operating when submerged.
(d) A secondary means of operating the valves, which may be local manual control, is to be provided.

2.5.5 Control systems should be designed to 'fail-safe'. The characteristics of the 'fail-safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.6 Fire detection alarm systems

2.6.1 Where an automatic fire detection system is to be fitted in a machinery space, the requirements of *Pt 6, Ch 1, 2.6 Fire detection alarm systems 2.6.2* are to be satisfied.

2.6.2 A fire detector indicator panel is to be located in such a position that a fire in the machinery spaces will not render it inoperable.

2.6.3 The audible fire-alarm is to have a characteristic tone which distinguishes it from any other alarm system. The audible fire-alarm is to be audible on all parts of the bridge and in the accommodation areas.

2.6.4 The alarm system should, so far as practicable, be designed with self-monitoring properties.

2.6.5 Failure of any power supply to the alarm system is to be indicated.

2.6.6 Detector heads of an approved type are to be located in the machinery spaces so that all potential fire outbreak points are guarded.

2.6.7 The fire detection system is to be capable of being tested.

2.6.8 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective.

2.6.9 Fire detecting indicating panels are to denote, as a minimum, the section in which a detector or manually operated call point has operated. A section of detectors is not to cover more than 1 deck except a section which covers an enclosed stairway. No section of detectors is in general to include more than 50 detectors.

2.6.10 A section of fire detectors which covers loops of accommodations and control stations is not to include high fire risk spaces.

2.6.11 At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge.

2.6.12 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section.

2.6.13 A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.6.14 A drawing showing the location of the fire detector heads and the fire indicator panel, is to be submitted.

2.6.15 Fire detection control units, indicating panels, detector heads and manual call points are to be Type Approved in accordance with Test Specification Number 1 given in LR's Type Approval System.

2.7 Programmable electronic systems – General requirements

2.7.1 The requirements of *Pt 6, Ch 1, 2.7 Programmable electronic systems – General requirements 2.7.2* are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical application and systems incorporating shared data communication links are to comply with the additional requirements of *Pt 6, Ch 1, 2.8 Data communication links* and *Pt 6, Ch 1, 2.9 Programmable electronic systems – Additional requirements for essential services and safety critical systems* as applicable.

2.7.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of *Pt 6, Ch 1, 2.7 Programmable electronic systems – General requirements*related to providing those required functions.

2.7.3 Programmable electronic equipment is to revert to a defined safe state on initial start-up or re-start in the event of failure.

2.7.4 In the event of failure of any programmable electronic equipment, the system, and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.7.5 Programmable electronic equipment is to be certified by a recognized authority as suitable for the environmental conditions in which it is intended to operate.

2.7.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment.

2.7.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of *Pt 6, Ch 1, 2.3 Alarm systems* and, where applicable, *Pt 6, Ch 1, 4.2 Alarm system for machinery*. Hardware failures are to be indicated at least at module level and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.7.8 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply.

2.7.9 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorized alteration.

2.7.10 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilized.

2.7.11 Displays and controls are to be protected against liquid ingress due to spillage.

2.7.12 User interfaces are to be designed in accordance with appropriate ergonomic principles to meet user needs and enable timely access to desired information or control of functions. A system overview is to be readily available.

2.7.13 The keyboard is to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

2.7.14 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

2.7.15 The size, colour and density of information displayed to the operator are to be such that information may be easily read from the normal operator position under all operational lighting conditions.

2.7.16 Display units are to comply with the requirements of International Electrotechnical Commission Standard IEC 60950:1991, *Safety of information technology equipment, including electrical business equipment*, in respect of emission of ionising radiation.

2.7.17 Symbols used in mimic diagrams are to be visually representative and are to be consistent throughout the systems' displays.

2.7.18 Mimic diagrams are to clearly identify unreliable data.

2.7.19 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system is required at the same time. At least one unit at the main control station is to be supplied from an independent uninterruptible power supply (UPS).

2.7.20 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.7.21 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003 Software engineering – *Guidelines for the application of ISO 9001:2015 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.8 Data communication links

2.8.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of *Pt 6, Ch 1, 2.8 Data communication links 2.8.2* are to be complied with. The requirements apply to local area networks, field buses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.8.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.8.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means.

2.8.4 The properties of the data communication link (e.g. bandwidth, access control method, etc.) are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.8.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.8.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of *Pt 6, Ch 1, 2.3 Alarm systems* and, where applicable, *Pt 6, Ch 1, 4.2 Alarm system for machinery* in the event of a failure of an active or standby component.

2.8.7 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.8.8 Data cables are to comply with the applicable requirements of *Pt 6, Ch 2, 7 Cables - Construction and testing*. Other media will be subject to special consideration.

2.8.9 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.8.10 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimized. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.9 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.9.1 The requirements of 2.9.2 to 2.9.9 are to be complied with where control, alarm or safety systems for essential services or safety critical systems, incorporate programmable electronic equipment:

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g. fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g. main engine low lubricating oil pressure shutdown).
(b) Applications that are not essential services may also be considered to be safety critical (e.g. domestic boiler low water level shutdown).

2.9.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be provided by a fully independent hard-wired backup system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994).*

2.9.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1 (2002)*, adjusted where applicable for operation solely in Seasonal Zones, see also *Pt 6, Ch 2, 1.5 Ambient temperatures 1.5.1*.

2.9.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.9.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.9.6 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of *Pt 6, Ch 1, 2.3 Alarm systems* and, where applicable, *Pt 6, Ch 1, 4.2 Alarm system for machinery*.

2.9.7 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard-wired backup system, redundancy with design diversity, etc.

2.9.8 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.9.9 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

■ *Section 3* Control and supervision of machinery

3.1 General

3.1.1 When machinery, as defined in *Pt 6, Ch 1, 1.2 Plans 1.2.2*, is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators then it is to be provided with the arrangements specified in *Pt 6, Ch 1, 3.2 Engines for propulsion purposes*. Alternative arrangements which provide equivalent safeguards will be considered.

3.1.2 Means are to be provided to prevent leaks from high pressure fuel oil injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

3.2 Engines for propulsion purposes

3.2.1 The following systems are to be provided with alarms:

System:	*Alarm:*
Lubricating oil pressure for the engine including gearing	Low
Lubricating oil pressure for the engine including gearing	Failure, *see Pt 6, Ch 1, 3.2 Engines for propulsion purposes 3.2.2*
Cooling system(s) temperature	High
Cooling system(s) temperature	Excessively high, *see Pt 6, Ch 1, 3.2 Engines for propulsion purposes 3.2.3*
Overspeed, for >37 kW	High, *see also Pt 5, Ch 2, 5 Construction and welded structures*

3.2.2 In the case of the lubricating oil system, in addition to the alarm indication as required by *Pt 6, Ch 1, 3.2 Engines for propulsion purposes 3.2.1*, at complete loss of lubricating oil the engine is to be stopped automatically or alternatively a second and separate alarm is to be provided giving audible and visual warning in the wheelhouse and in the engine room. The circuit and sensor employed for the automatic stop or alarm are to be additional to the alarm circuit and sensor required by *Pt 6, Ch 1, 3.2 Engines for propulsion purposes 3.2.1*.

3.2.3 In the case of cooling system(s), in addition to the alarm indication as required by *Pt 6, Ch 1, 3.2 Engines for propulsion purposes 3.2.1*, a shutdown system for excessively high temperature may be fitted which is to be independent of the alarm system.

3.2.4 Prolonged running in a restricted speed range is to be prevented automatically; alternatively, indication of restricted speed ranges is to be provided at each control station.

3.3 Boilers and thermal fluid heaters

3.3.1 A system of water level detection is to be fitted which will operate alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

3.3.2 The fuel oil is to be shut off automatically from the burners, and alarms are to operate on flame failure and failure of combustion air supply detected by either low pressure at the fan outlet or stopping of the fan motor.

3.3.3 Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.

3.3.4 For cargo heating systems, circulation pumps are to stop automatically in the event of low level and in the event of low pressure of thermal fluid circulation.

3.4 Auxiliary engines

3.4.1 The following systems for auxiliary engines of more than 37 kW (50 shp) are to be provided with alarms:

System:	*Alarm:*
Lubricating oil pressure	Low*
Cooling system temperature	High*

*These alarms may be combined with an automatic shutdown system, if fitted. Automatic shutdowns for these items are not to be fitted on emergency engines.

3.5 Remote control for propulsion machinery

3.5.1 The following systems are to be provided with alarms:

System:	*Alarm:*
Operating medium for hydraulic or pneumatic coupling in propulsion system	Low pressure
Operating medium for hydraulic or pneumatic remote control system for main engine	Low pressure
Electrical supply to remote control system for main engine.	Loss of supply

3.6 Controllable pitch propellers and transverse thrust units

3.6.1 Preferred alarms and safeguards are indicated in *Pt 6, Ch 1, 3.6 Controllable pitch propellers and transverse thrust units 3.6.2*.

3.6.2 In the case of main propulsion systems, means are to be provided to prevent the engines and shafting being subjected to excessive torque due to changes in propeller pitch; alternatively an engine overload indicator may be fitted at each station from which it is possible to control the pitch of the propeller.

3.6.3 Where transverse thrust units are remotely controlled, means are to be provided at the remote control station to stop the propulsion unit.

3.6.4 The following systems are to be provided with alarms:

System:	*Alarm:*
Hydraulic system pressure	Low
Power supply to the control system between the remote control station and hydraulic actuator.	Loss of supply

3.7 Steering gear

3.7.1 For power operated steering gear, safeguards and alarms are to be provided as indicated in *Pt 6, Ch 1, 3.7 Steering gear 3.7.2* and *Pt 6, Ch 1, 3.7 Steering gear 3.7.5*.

3.7.2 Provision should be made at the bridge to ensure that the steering gear may be rapidly and effectively transferred to an alternative power and control system, which may be manual.

3.7.3 Where the alternative steering gear system is also power operated, this system should be independent of the main power system.

3.7.4 The control system for the alternative steering gear system required by *Pt 6, Ch 1, 3.7 Steering gear 3.7.2* is to be independent of the main steering gear control system.

3.7.5 The following systems are to be provided with alarms:

System:	*Alarm:*
Steering gear power systems(s)	Failure
Steering gear control systems(s)	Failure
Steering gear hydraulic oil tank level	Low

3.8 Main propulsion shafting

3.8.1 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm.

3.9 Liftable wheelhouse systems

3.9.1 For a general description and definitions of Liftable wheelhouse systems, *see Pt 3, Ch 13, 1 General requirements*.

3.9.2 Liftable wheelhouse systems are to be provided with starting and stopping arrangements designed to prevent abrupt accelerations and decelerations when moving the wheelhouse.

3.9.3 Duplicated, independent power supplies, valves, pumps (if required) and hoses to permit emergency lifting and lowering in the event of failure of a duplicated item are to be provided, *see also Pt 6, Ch 1, 3.9 Liftable wheelhouse systems 3.9.4*.

3.9.4 Easily accessible controls for emergency lifting and lowering is to be provided in the wheelhouse which are to be independent from the main controls.

3.9.5 Cable routing of controls is to be carried out in a reliable way avoiding any possible damage during the operation of the ship or wheelhouse.

3.9.6 Any movement of the wheelhouse is to engage an audible alarm.

3.9.7 Permanent warning notices are to be displayed at accesses to the columns and at control stations indicating potential danger to personnel in the columns due to lifting or lowering movements.

3.9.8 Controls are to be failsafe.

3.9.9 Sufficient cable length should be provided to enable unobstructed movements of the cables when moving the columns. The occurrence of sharp bends in the cables and the possibility of cable damage is to be prevented. Cables are to be suitable for the intended purpose.

■ *Section 4*
Ships operating with unattended machinery spaces

4.1 General

4.1.1 Where it is intended to operate the propulsion machinery and associated systems whilst the machinery space is not continuously attended, the controls and alarms required by *Pt 6, Ch 1, 3 Control and supervision of machinery*, together with those given in *Pt 6, Ch 1, 4.2 Alarm system for machinery* are to be provided.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery and control systems is to be installed. The system is to satisfy the requirements of *Pt 6, Ch 1, 2.3 Alarm systems*.

4.3 Bridge control for main propulsion machinery

4.3.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both ahead and astern directions.

4.3.2 Instrumentation to indicate the following is to be fitted on the bridge:

(a) Propeller speed.
(b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for controllable pitch propeller.
(c) Clutch position where applicable.
(d) Shaft brake position where applicable.

4.3.3 Means of control, independent of the bridge control system, are to be provided on the bridge to enable the watchkeeper to stop the propulsion machinery in an emergency. When the bridge control consists of a system with mechanical linkages only, such an emergency stop system is not required.

4.4 Fire detection alarm system

4.4.1 An automatic fire detection system, together with an audible and visual alarm system is to be fitted in the machinery spaces of Type N Open with flame screens oil tankers, oil and chemical tankers, chemical tankers and liquefied gas carriers when these ships have a propulsion machinery of 740 kW or more.

4.5 Bilge level alarm system

4.5.1 An alarm is to be provided to warn that liquid in the machinery space bilges has reached a predetermined level. The location of sensors for bilge alarms is to be clearly marked to allow identification by responsible personnel and the sensors are to be provided with means of access for inspection that does not require the use of tools.

■ *Section 5*
Trials

5.1 New or amended installations

5.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the test schedules list as required in*Pt 6, Ch 1, 1.2 Plans 1.2.1*.

■ *Section 1*
General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to self-propelled and non-self-propelled ships for service on Inland Waterways except where otherwise stated. Attention should also be given to any relevant requirements of National, International or Local Authorities which will apply to the ship in service.

1.1.2 In passenger ships, services essential for safety are to be maintained under emergency conditions and the safety of ship and personnel from electrical hazards is to be assured.

1.1.3 Electrical installations are to be constructed and installed in accordance with the relevant Sections of this Chapter and are to be inspected and tested by the Surveyors. Compliance with the requirements of an acceptable National or International Standard, e.g. Regulations of the A.D.N. (A.D.N.) may be accepted as meeting the requirements of this Chapter, subject to inspection and testing by the Surveyors.

1.1.4 The Committee will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules. Consideration will also be given to the electrical arrangements of small ships and ships to be assigned class notations for a specified limited service.

1.2 Plans

1.2.1 The plans and particulars in *Pt 6, Ch 2, 1.2 Plans 1.2.2* are to be submitted, in triplicate, for consideration.

1.2.2 **Electrical equipment**. The arrangement plan and circuit diagram of the switchboard(s). Diagrams of the wiring system including cable sizes, type of insulation, normal working current in the circuits, and the capacity, type and make of protective devices. Calculations of short-circuit currents at main busbars, sub-switchboard busbars and the secondary side of transformers are to be submitted.

1.2.3 **Oil tankers, oil and chemical tankers and chemical tankers.** A general arrangement of the ship showing hazardous zones or spaces and the location of electrical equipment in such zones or spaces. A schedule of safe type electrical equipment located in hazardous zones or spaces giving details of the type of equipment fitted, the certifying Authority, the certificate number and copies of the certificates.

1.2.4 **Prime movers.** *See Pt 1, Ch 3, 12 Electrical equipment*.

1.2.5 Centralized, bridge or automatic controls. *See Pt 6, Ch 1 Control Engineering Systems* and*Pt 5, Ch 2 Engines*.

1.3 Additions or alterations

1.3.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current-carrying capacity and the condition of the existing accessories, conductors and switchgear are adequate for the increased load. *See Pt 1, Ch 3, 12 Electrical equipment*.

1.3.2 Plans are to be submitted for approval, and the alterations or additions are to be carried out under the inspection, and to the satisfaction of the Surveyors.

1.4 Application

1.4.1 Except where a specific statement is made to the contrary, all requirements of this Chapter are applicable to both alternating current and direct current installations.

1.4.2 Direct current equipment is to operate satisfactorily under voltage fluctuations of plus six per cent and minus 10 per cent.

1.4.3 Alternating current equipment is to operate satisfactorily under voltage fluctuations of plus six per cent and minus 10 per cent at rated frequency, and under frequency fluctuations of plus or minus five per cent at rated voltage.

1.4.4 Contactors and similar equipment are not to drop out at or above 85 per cent rated voltage.

1.5 Ambient temperatures

1.5.1 The following cooling air and cooling water temperatures are applicable in ships intended for operation in:

(a) **Tropical Zones**

Primary cooling water supply 30°C.

Cooling air temperature 45°C.

(b) **Seasonal Zones**

Vessels intended solely for use in northern or southern

waters outside the tropical belt.

Primary cooling water supply 25°C.

Cooling air temperature 40°C.

1.6 Location and construction

1.6.1 Electrical equipment is to be accessibly placed, clear of flammable material in well-ventilated, adequately lighted spaces in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical injury or damage from water, steam or oil. Where necessarily exposed to such risks, the equipment is to be suitably constructed or enclosed. Live parts are to be guarded where necessary.

1.6.2 The operation of all electrical equipment and the lubricating arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.6.3 All nuts and screws used in connection with the current-carrying parts and working parts are to be effectively locked.

1.7 Earthing

1.7.1 Non-current-carrying metal parts of electrical equipment are to be effectively earthed. Where earthing connections are necessary, they are to be of copper or other approved material and are to be protected against damage and, where necessary, electrolytic action. In general, they are to be equal to the cross-section of the current-carrying conductor up to 16 mm2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2.

1.7.2 **Portable equipment.** Metal frames of all portable electric lamps, tools and similar apparatus supplied as ship's equipment and rated in excess of 55 V are to be earthed through a suitable conductor unless equivalent safety provisions are made such as by double insulation or by an isolating transformer.

1.8 Creepage and clearance

1.8.1 The distances between live parts and between live parts and earthed metal, whether across surfaces or in air, shall be adequate for the working voltage having regard to the nature of the insulating material and the transient over-voltages developed by switch and fault conditions.

1.9 Electrical equipment for use in explosive gas atmospheres

1.9.1 Where electrical equipment is installed in areas where explosive gas atmospheres may be present, it is to be 'safe type' as defined by IEC 60079: *Electrical Apparatus for Explosive Gas Atmospheres*, or an equivalent national specification.

1.9.2 Copies of type test certificates by a competent independent Testing Authority are to be made available.

1.9.3 For oil tankers, oil and chemical tankers and chemical tankers, *see Pt 6, Ch 2, 13 Special requirements for tankers intended for the carriage in bulk of oil and other hazardous liquids*, *Pt 6, Ch 2, 14 Additional requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point of 60°C and below (closed cup test)* and *Pt 6, Ch 2, 15 Additional requirements for tankers intended for the carriage in bulk of other hazardous liquids*.

■ *Section 2* System design - General

2.1 Systems of distribution

2.1.1 The following systems of distribution may be used:

(a) Parallel systems with constant voltage

- (i) d.c., two-wire
- (ii) a.c., single-phase, two-wire
- (iii) a.c., three-phase,

  three-wire

  four-wire with neutral earthed

Systems employing hull return will be accepted except for final sub-circuits which are to be 2-pole insulated.

(b) Series systems with constant current (direct current only).

2.1.2 For parallel systems with constant voltage, system voltages for both alternating current and direct current shall not exceed:

500 V for generation, power, cooking and heating equipment permanently connected to fixed wiring.

250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above.

2.1.3 Generation and distribution at higher voltages may be submitted for special consideration.

2.2 Earth indication

2.2.1 Every insulated distribution system is to be provided with lamps or other means to indicate the state of insulation to earth.

2.2.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the event of an abnormally low level of insulation resistance.

2.3 Number and rating of generating sets

2.3.1 The number and rating of the ship's service generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship.

2.3.2 On oil tankers, oil and chemical tankers, chemical tankers, cargo and passenger ships where electrical power is required for essential equipment, the generating plant and converting plant is to be of such capacity that this essential equipment can be operated satisfactorily even with one generating set or converting set out of action.

2.3.3 In alternating current systems requiring standby equipment, *see Pt 6, Ch 2, 2.3 Number and rating of generating sets 2.3.1*, with one generating set out of action, the remaining set(s) are to have sufficient reserve capacity to permit the starting of the largest motor in the ship without causing any motor to stall or any other device to fail due to excessive voltage drop on the system.

2.4 Emergency source of power in passenger ships

2.4.1 All passenger ships are to be provided with an emergency source of electrical power. Location is to be aft of collision bulkhead and A60 separated from main generators and in a watertight separated compartment when available.

2.4.2 Where emergency generating sets are fitted, they are to be capable of being started readily when cold.

2.4.3 If hand starting is demonstrated to be practicable, alternative means of starting are not required. Where hand starting is not practicable, other means are to be provided and, in general, should provide for not less than 12 starts in a period of 30 minutes without recourse to sources within the machinery space.

2.4.4 The power available is to be sufficient to supply all services necessary for the safety of passengers and crew in an emergency, due regard being paid to such services as may have to be operated simultaneously. Special consideration is to be given to emergency lighting in all alleyways, stairways and exits, in the machinery spaces and in the control stations (i.e. spaces in which radio, main navigating or central fire recording equipment or the emergency generator is located), to fire detection and alarm systems, to the emergency fire pump if electrically driven, automatic sprinkler systems, if fitted, and to navigation lights. The power is to be adequate for a period of three hours.

2.4.5 The emergency source of power is to be either:

(a) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel used is to have a flash point of not less than 43°C; or
(b) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop.

2.4.6 Where the emergency source of power is an accumulator battery, arrangements are to be such that emergency lighting will automatically come into operation on failure of the main lighting supply.

2.4.7 An indicator is to be mounted in the machinery space, or in the wheelhouse, to indicate when any accumulator battery fitted in accordance with *Pt 6, Ch 2, 2.4 Emergency source of power in passenger ships 2.4.5* is being discharged.

2.4.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of power.

2.4.9 The emergency switchboard may be supplied from the main switchboard during normal operation.

2.4.10 Emergency source/distribution is to be independent from main source/distribution and main source/distribution is to be independent of emergency source/distribution.

2.5 Diversity factor

2.5.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

2.5.2 The diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear.

2.6 Motor circuits

2.6.1 A separate final sub-circuit is to be provided for every motor required for essential services.

2.7 Lighting circuits

2.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. (This does not apply to cabin fans and wardrobe heaters).

2.7.2 A final sub-circuit of rating exceeding 15 A is not to supply more than one point. The number of lighting points supplied by a final sub-circuit of rating 15 A or less is not to exceed:

10 for 24	–	55 V circuits,
14 for 110	–	127 V circuits,
18 for 220	–	250 V circuits,

except that in final sub-circuits for cornice lighting, panel lighting and electric signs where lampholders are closely grouped, the number of points supplied is unrestricted, provided the maximum operating current in the sub-circuit does not exceed 10 A.

2.7.3 Lighting of cargo spaces is to be controlled by multi-pole linked switches situated outside these spaces. Provision is to be made for the complete isolation of these circuits and locking in the off position of the means of control.

2.7.4 Emergency lighting is to be fitted in accordance with *Pt 6, Ch 2, 2.4 Emergency source of power in passenger ships 2.4.4*.

2.8 Steering gear

2.8.1 Where electrical control of the steering system is fitted, an independent alternative control system is to be installed. This may be a duplicate electrical control system or control by other means.

2.8.2 Provision should be made on the bridge to effectively transfer the steering control instantaneously to the alternative means of control.

2.8.3 Indicators for running indication of steering gear motors are to be installed on the bridge.

2.8.4 Audible and visual alarms are to operate at the steering position(s) for the following fault conditions:

(a) Failure of steering gear power system(s).
(b) Failure of steering gear control system(s).

2.9 Fire detection, alarm and extinguishing systems on passenger ships

2.9.1 Where electrically driven emergency fire pumps are installed in accordance with *Pt 6, Ch 2, 17.4 Emergency services 17.4.1*, the supply to such pumps is not to pass through the main machinery spaces.

2.9.2 Any fire-alarm system is to operate both audible and visual signals at the fire detection control station(s).

2.10 Navigation lights

2.10.1 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted in the distribution board.

2.10.2 Automatic indication of failure is to be provided unless lights are visible from the bridge.

2.10.3 Any Statutory Requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

2.11 Remote stops for ventilating fans and pumps

2.11.1 Means are to be provided for stopping ventilating fans serving machinery and cargo spaces. These means are to be capable of being operated from outside such spaces in case of fire.

2.11.2 Machinery driving boiler fans, independently driven pumps delivering oil to main propulsion machinery for bearing lubrication and piston cooling, fuel oil transfer pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

2.11.3 In passenger ships, all power ventilation systems, except cargo and machinery space ventilation, which is to be in accordance with *Pt 6, Ch 2, 2.11 Remote stops for ventilating fans and pumps 2.11.1*, are to be fitted with master controls so that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.

2.12 Motor control

2.12.1 Every electric motor is to be provided with efficient means of starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in *Pt 6, Ch 2, 2.12 Motor control 2.12.2* .

2.12.2 Means are to be provided to prevent undesired restarting after a stoppage due to low volts or complete loss of volts. This does not apply to motors, the continuous availability of which is essential to the safety of the ship.

2.12.3 Efficient means of isolation are to be provided so that all voltage may be cut off from the motor and any associated apparatus including any automatic circuit-breaker.

2.12.4 Where the primary means of isolation (that provided at the switchboard, section board or distribution fuse board) is remote from a motor, one of the following is to be provided:

(a) An additional means of isolation fitted adjacent to the motor; or
(b) provision made for locking the primary means of isolation in the OFF position; or
(c) provision made so that the fuses in each line can be readily removed and retained by authorized personnel.

2.12.5 Means are to be provided for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor.

2.12.6 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

2.12.7 When motor controlgear is being selected, the maximum current of a motor is to be taken as the full load rated current of the motor.

2.13 Size of batteries and charging facilities

2.13.1 Where batteries are used for starting main engines, they are to be of adequate capacity to meet the requirements of *Pt 5, Ch 2, 9 Starting arrangements, air compressors and batteries*.

2.13.2 Adequate charging facilities are to be provided, and where batteries are charged from line voltage, by means of a series resistor, protection against reversal of current is to be provided when the charging voltage is 20 per cent of line voltage or higher.

2.13.3 In direct current systems, means are to be provided to isolate the batteries from the low voltage system when being charged from a higher voltage system.

2.14 Communications

2.14.1 For the requirements of the provision of a communication system on board passenger ships, *see Pt 6, Ch 2, 17.5 Passenger and crew warning system* and *Pt 6, Ch 2, 17.6 General emergency alarm system*.

2.15 Heating and cooking equipment

2.15.1 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters a single-pole switch will be acceptable.

2.16 Shore supply

2.16.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a suitable connection box is to be installed in a position in the ship suitable for the convenient connection of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals of ample size and suitable shape to facilitate a satisfactory connection. Suitable cables, permanently fixed, are to be provided connecting the terminals to a linked switch and/or a circuit-breaker at the main switchboard.

2.16.2 An earth terminal is to be provided for connecting the hull to the shore earth.The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energized.

2.16.3 The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energized.

2.16.4 Means are to be provided for checking the polarity (for direct current) or the phase sequence (for three – phase alternating current) of the incoming supply in relation to the ship's system.

2.16.5 At the connection box, a notice is to be provided giving full information on the system of supply and the normal voltage (and frequency, if alternating current) of the ship's system and the procedure for carrying out the connection.

2.16.6 Alternative arrangements may be submitted for consideration.

2.17 Choice of cables

2.17.1 Cables are to be in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in *Pt 6, Ch 2, 1.5 Ambient temperatures 1.5.1*.

2.17.2 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

2.18 Choice of insulating material

2.18.1 The rated operating temperature of the insulating material is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

2.19 Choice of protective covering

2.19.1 Cables fitted in the following locations:

Decks exposed to the weather

Bathrooms

Cargo holds

Machinery spaces

or in any other location where water condensation or harmful vapour (e.g. oil vapour) may be present are to have an impervious sheath. In permanently wet situations, metallic sheaths are to be used for cables with hygroscopic insulation.

2.19.2 All cables are to be of flame-retardant or of fire-resisting type, except that flame-extending cables may be used for final circuits where cables are installed in metallic conduits having an internal diameter not exceeding 25 mm and provided the conduits are mechanically and electrically continuous.

2.20 Current rating

2.20.1 The highest continuous load carried by a cable is not to exceed its current rating. The diversity factor of the individual loads and the duration of the maximum demand may be allowed for in estimating the maximum continuous load and is to be shown on plans submitted for approval.

2.20.2 The voltage drop from the main switchboard busbars to any point in the installation when the cables are carrying maximum current under normal conditions of service, is not to exceed six per cent of the nominal voltage.

2.20.3 In assessing the current rating of lighting circuits, every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 W, unless the fitting is so connected as to take only a lamp rated at less than 60 W.

2.20.4 Cables supplying cargo winches, cranes, windlasses and capstans are to be suitably rated for their duty. Unless the duty is such as to require a longer time rating, cables for winch or crane motors may be half hour rated on the basis of the half hour kW rating of the motors. Cables for windlass and capstan motors are to be not less than one hour rated on the basis of the one hour kW rating of the motor. In all cases the rating is to be subject to the voltage drop being within the specified limits.

2.20.5 The current ratings given in *Table 2.2.2 General purpose rubber and PVC* are based on maximum operating conductor temperatures given in *Table 2.2.1 Maximum operating conductor*. Alternatively, current rating in accordance with an acceptable National or International Standard may be applied, *see Pt 6, Ch 2, 2.17 Choice of cables 2.17.1*.

Table 2.2.1 Maximum operating conductor

Insulating material	Maximum rated conductor temperature, °C
ELASTOMERIC COMPOUNDS	
Natural or synthetic rubber (general purpose)	60
Butyl rubber	80
Ethylene propylene rubber	85
Cross-linked polyethylene	85
Silicone rubber	95
THERMOPLASTIC COMPOUNDS	
Polyvinyl chloride (general purpose)	60
Polyvinyl chloride (heat resisting quality)	75
OTHER MATERIALS	
Mineral	95
Note 1. Silicone rubber and mineral insulation may be used for higher temperatures (to 150°C for silicone rubber, unlimited for mineral insulation) when installed where they are not liable to be touched by ship's personnel. Proposals to employ these higher temperatures will be specially considered.	
Note 2. The temperature of the conductor is the combination of ambient temperature and temperature rise due to load.	

Table 2.2.2 General purpose rubber and PVC

Nominal cross-section	Current rating (Based on ambient temp. 40°C)		
	Single core	2 core	3 or 4 core
mm^2	amperes	amperes	amperes
1	9	8	7
1,5	14	12	9
2,5	20	16	14
4	25	22	17
6	33	29	23
10	46	39	32
16	62	53	43
25	82	69	56
35	100	85	70
50	121	102	84
60	138	115	97
70	155	132	108
95	190	161	132

120	219		185		153	
150	253		215		177	
185	288		244		201	
240	336		283		234	
300	385		328		269	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	449	437	380	374	316	311
500	518	495	437	420	363	345
625	598	541	506	432	414	380

Table 2.2.3 Heat resisting PVC

Nominal cross-section	Current rating (Based on ambient temp. 40°C)					
	Single core		2 core		3 or 4 core	
mm^2	amperes		amperes		amperes	
1	14		12		10	
1,5	18		15		13	
2,5	26		22		18	
4	35		29		24	
6	44		38		31	
10	62		53		43	
16	82		69		57	
25	108		93		77	
35	135		113		95	
50	162		137		113	
60	189		162		135	
70	205		174		144	
95	248		211		174	
120	292		248		205	
150	335		286		232	
185	378		324		265	
240	448		383		313	
300	513		436		359	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	616	605	524	513	432	421

500	702	670	594	572	491	470
625	799	724	680	616	562	508

Table 2.2.4 Butyl

Nominal cross-section	Current rating (Based on ambient temp. 40°C)					
	Single core		2 core		3 or 4 core	
mm^2	amperes		amperes		amperes	
1	16		13		11	
1,5	20		17		14	
2,5	28		24		19	
4	37		32		27	
6	48		41		34	
10	67		57		47	
16	90		76		63	
25	118		96		82	
35	150		127		105	
50	177		150		123	
60	198		171		139	
70	230		196		161	
95	278		235		195	
120	321		273		225	
150	364		310		255	
185	417		355		292	
240	492		417		345	
300	567		482		396	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	653	631	556	535	455	444
500	739	685	631	589	519	482
625	845	739	728	621	589	514

Table 2.2.5 Ethylene propylene rubber, crosslinked

Nominal cross-section	Current rating (Based on ambient temp. 40°C)		
	Single core	2 core	3 or 4 core
mm^2	amperes	amperes	amperes

1	17		14		12	
1,5	21		18		15	
2,5	30		24		20	
4	40		34		28	
6	51		42		35	
10	71		60		50	
16	95		81		67	
25	127		108		89	
35	154		127		106	
50	191		164		133	
60	212		180		148	
70	239		202		166	
95	292		248		205	
120	339		294		237	
150	387		329		270	
185	440		373		307	
240	519		441		364	
300	594		505		416	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	689	668	583	572	482	466
500	784	731	668	625	551	509
625	901	774	763	657	625	541

Table 2.2.6 Silicone rubber, mineral

Nominal cross-section	Current rating (Based on ambient temp. 40°C)		
	Single core	2 core	3 or 4 core
mm^2	amperes	amperes	amperes
1	21	18	15
1,5	25	21	18
2,5	34	38	23
4	44	38	30
6	58	49	36
10	79	67	55
16	105	89	74

25	142	121	99
35	173	147	121
50	210	184	152
60	242	205	168
70	268	228	188
95	325	278	226
120	378	320	263
150	431	368	301
185	494	420	345
240	599	509	420
300	693	588	483

2.21 Correction factors for current rating

2.21.1 **Ambient temperature.** When it is known that the ambient temperature is different from that given in *Pt 6, Ch 2, 1.5 Ambient temperatures*, correction factors shown in *Table 2.2.7 Correction factors for ambient* are to be applied.

Table 2.2.7 Correction factors for ambient

Insulation	Correction factor for ambient temperature			
	40°C	45°C	50°C	55°C
Rubber or PVC (general purpose)	1,00	0,87	0,71	—
PVC (heat-resisting quality)	1,00	0,93	0,84	0,76
Butyl rubber	1,00	0,93	0,84	0,80
Ethylene propylene rubber, cross linked polyethylene	1,00	0,94	0,89	0,82
Mineral, silicone rubber	1,00	0,95	0,90	0,85

2.21.2 **Intermittent service.** Where the load is intermittent, the correction factors in *Table 2.2.8 Correction factors for intermettent* may be applied for half hour and one hour ratings. In no case is a shorter rating than one half hour rating to be used, whatever the degree of intermittency.

Table 2.2.8 Correction factors for intermettent

Correction factor	Half-hour rating		One hour rating	
	With metallic sheath	Without metallic sheath	With metallic sheath	Without metallic sheath
	mm^2	mm^2	mm^2	mm^2
1,0	Up to 20	Up to 75	Up to 67	Up to 230
1,1	21 – 40	76 – 125	68 – 170	231 – 400
1,15	41 – 65	126 – 180	171 – 290	401 – 600
1,2	66 – 95	181 – 250	291 – 430	–
1,25	96 – 130	251 – 320	431 – 600	–

1,3	131 – 170	321 – 400	–	–
1,35	171 – 220	401 – 500	–	–
1,4	221 – 270	–	–	–

2.22 Arrangement of cables

2.22.1 Cables having insulating materials with different maximum-rated conductor temperatures are not to be bunched together, or where this is not practicable, the cables are to be so operated that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.

2.23 Connections between entrained ships

2.23.1 Cables are to be suitable for use in the connections between entrained ships, i.e. are to be flexible, robust and of commensurate cross-section area.

2.23.2 The connection is to include provisions for the continuity of out-of-balance or earth-fault current return. The connecting device is to include provisions to ensure that this circuit is closed before, and opened after, the live circuits.

2.23.3 Terminal plugs and sockets, if used, are to be so arranged that any exposed pins cannot be energized, *see Pt 6, Ch 2, 10.3 Socket outlets and plugs*for additional requirements.

2.23.4 Where hull-return systems are used, hull polarity is to be compatible.

■ *Section 3*
System design - Protection

3.1 General

3.1.1 Installations are to be protected against accidental overcurrents including short-circuit. The protective devices are to provide complete and co-ordinated protection to ensure:

(a) Continuity of service under fault conditions through discriminative action of the protective devices.
(b) Elimination of the fault to reduce damage to the system and hazard of fire.

3.2 Protection against overload

3.2.1 Circuit-breakers and automatic switches provided for overload protection are to have tripping characteristics appropriate to the system. Fuses above 320 A are not to be used for overload protection, but may be used for short-circuit protection.

3.3 Protection against short-circuit

3.3.1 Protection against short-circuit currents is to be provided.

3.3.2 The breaking capacity of every protective device is to be not less than the maximum value of the short-circuit current which can flow at the point of installation at the instant of contact separation.

3.3.3 The making capacity of every switching device intended to be capable of being closed, if necessary, on short-circuit, is to be not less than the maximum value of the short-circuit current at the point of installation. On alternating current, this maximum value corresponds to the peak value allowing for maximum asymmetry.

3.3.4 Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current which can occur at the point of installation having regard to the time required for the short-circuit to be removed.

3.3.5 In the absence of precise data, the following short-circuit currents at the machine terminals are to be assumed:

(a) Direct current systems

10 times full load current for generators normally connected (including spare). Six times full load current for motors simultaneously in service.

(b) Alternating current systems

10 times full load current for generators normally connected (including spare) – symmetrical r.m.s. Three times full load current for motors simultaneously in service.

3.4 Combined circuit-breakers and fuses

3.4.1 The use of a circuit-breaker of breaking capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded on the generator side by fuses, or by a circuit-breaker having at least the necessary breaking capacity. The generator breakers are not to be used for this purpose.

3.4.2 Fused circuit-breakers with fuses connected to the load side may be used where operation of the circuit-breaker and fuses is co-ordinated.

3.4.3 The characteristics of the arrangement shall be such that:

(a) When the short-circuit current is broken, the circuit-breaker on the load side shall not be damaged and is to be capable of further service.
(b) When the circuit-breaker is closed on the short-circuit current, the remainder of the installation shall not be damaged. However, it is admissible that the circuit-breaker on the load side may require servicing after the fault has been cleared.

3.5 Protection of circuits

3.5.1 Short-circuit protection is to be provided in each live pole of a direct current system and in each phase of an alternating current system.

3.5.2 Overload protection is to be provided in:

(a) Two-wire direct current or single-phase alternating current system – at least one line or phase.
(b) Three-wire direct current system – both outer lines.
(c) Insulated three-phase alternating current system – at least two phases.
(d) Earthed three-phase alternating current system – all three phases.

3.5.3 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors.

3.5.4 These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

3.6 Protection of generators

3.6.1 In addition to the protection required by *Pt 6, Ch 2, 3.5 Protection of circuits 3.5.1* and *Pt 6, Ch 2, 3.5 Protection of circuits 3.5.2*, protective gear required by *Pt 6, Ch 2, 3.6 Protection of generators 3.6.2*, is to be provided as a minimum.

3.6.2 For generators not arranged to run in parallel: A circuit-breaker or contactor arranged to open simultaneously all insulated poles or in the case of generators rated at less than 50 kW a multi-pole linked switch with a fuse in each insulated pole.

3.6.3 For generators arranged to operate in parallel: A circuit-breaker or contactor arranged to open simultaneously all insulated poles and provided with:

(a) For direct current generators, instantaneous reverse-current protection operating at not more than 15 per cent rated current.
(b) For alternating current generators, a reverse-power protection, with time delay, selected and set within the limits of two per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover.

3.6.4 The reverse-current protection is to be adequate to deal with the reverse-current conditions emanating from the ship's network, e.g. winches.

3.7 Feeder circuits

3.7.1 Isolation and protection of each main distribution circuit is to be ensured by a multi-pole circuit breaker or switch and fuses. Protection is to be in accordance with *Pt 6, Ch 2, 3.2 Protection against overload*, *Pt 6, Ch 2, 3.3 Protection against short-circuit*and *Pt 6, Ch 2, 3.5 Protection of circuits*. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

3.7.2 Circuits which supply motors fitted with overload protection may be provided with short-circuit protection only.

3.7.3 Motors of rating exceeding 0,5 kW are to be protected individually against overload and short-circuit. The short-circuit protection can be provided by the same protective device for the motor and its supply cable. The overload protection may be replaced by an overload alarm if desired by the Owner.

3.8 Power transformers

3.8.1 The primary circuits of power transformers are to be protected against short-circuit by circuit-breakers or fuses.

3.8.2 When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit-breakers are to be capable of withstanding surge currents.

3.9 Lighting circuits

3.9.1 Lighting circuits are to be provided with overload and short-circuit protection.

3.9.2 Where more than one light is installed in a space, the lighting is to be supplied from at least two final sub-circuits in such a way that failure of one of the circuits does not leave the space in darkness.

3.10 Meters, pilot lamps, capacitors

3.10.1 Protection is to be provided for voltmeters, voltage coils of measuring instruments, earth indicating devices and pilot lamps, together with their connecting leads.

3.10.2 A pilot lamp installed as an integral part of another item of equipment need not be individually protected, provided it is fitted in the same enclosure.

3.11 Batteries

3.11.1 Batteries, except starter batteries, are to be protected against short-circuit by a fuse in each insulated conductor or a multi-pole circuit-breaker at a position adjacent to the battery compartment.

■ *Section 4*
Rotating machines

4.1 General

4.1.1 Rotating machines are to be constructed in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in *Pt 6, Ch 2, 1.5 Ambient temperatures*.

4.1.2 The entity responsible for assembling the alternating current generating set is to install a rating plate marked with at least the following information:

(a) the generating set manufacturer’s name or mark;
(b) the set serial number;
(c) the set date of manufacture (month/year);
(d) the rated power (both in kW and kVA) with one of the power rating prefixes COP, PRP (or, only for emergency generating sets, LTP) as defined in ISO 8528-1 *Reciprocating internal combustion engine driven alternating current generating sets*;
(e) the rated power factor;
(f) the set rated frequency (Hz);
(g) the set rated voltage (V);
(h) the set rated current (A); and
(i) the mass (kg).

4.2 Rating

4.2.1 Ships’ service generators, including their exciters, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in*Pt 6, Ch 2, 4.3 Temperature rise* being exceeded. Other generators and motors are to be rated in accordance with the duty which they are to perform, and when tested under rated load conditions the temperature rise is not to exceed the values in *Pt 6,*

Ch 2, 4.3 Temperature rise. Alternatively, limits of temperature rise in accordance with an acceptable National or International Standard may be applied, *see Pt 6, Ch 2, 4.1 General 4.1.1*.

4.3 Temperature rise

4.3.1 *Table 2.4.1 Temperature rise in °C calculated on the basis of a cooling air temperature not exceeding 40°C* gives the limits of temperature rise above the cooling air temperature, calculated on the basis of a cooling air temperature not exceeding 40°C.

Table 2.4.1 Temperature rise in °C calculated on the basis of a cooling air temperature not exceeding 40°C

Limits of temperature rise of machines cooled by air, °C								
Part of machine			Method of temperature measurement	Insulation class				
				A	E	B	F	H
1.	(a)	a.c. windings of machines having output of 5000 kVA or more	ETD R	60 55	— —	85 75	100 95	120 115
	(b)	a.c. windings of machines having output of less than 5000 kVA	ETD R	60 55	— 70	85 75	105 100	120 115
2.	Windings of armatures having commutators		R T	55 45	70 60	75 65	100 80	120 100
3.	Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4		R T	55 45	70 60	75 65	100 80	120 100
4.	(a)	Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	—	—	85	105	130
	(b)	Stationary field windings of d.c. machines having more than one layer	R T	55 45	70 60	75 65	100 80	120 100
	(c)	Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R,T	55	70	75	95	120

	(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R,T	60	75	85	105	130
5.	Permanently short-circuited insulated windings	T	55	70	75	95	120
6.	Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7.	Magnetic cores and other parts not in contact with windings	T					
8.	Magnetic cores and other parts in contact with windings	T	55	70	75	95	115
9.	Commutators and slip-rings open and enclosed	T	55	65	75	85	95
Note 1. Where water cooled heat exchangers are used in the machine cooling circuit, the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in *Table 2.4.1 Temperature rise in °C calculated on the basis of a cooling air temperature not exceeding 40°C* shall be increased by 10°C provided the inlet water temperature does not exceed the values given in *Pt 6, Ch 2, 1.5 Ambient temperatures*. Note 2. T = thermometer method R = resistance method ETD = embedded temperature detector Note 3. Temperature rise measurements are to use the resistance method whenever practicable. Note 4. The ETD method may only be used when the ETDs are located between coil sides in the slot.							

4.3.2 For machines intended to operate in ships intended for operation in tropical zones, as defined in *Pt 6, Ch 2, 1.5 Ambient temperatures*, the temperature rises given should be reduced by 5°C for all machines.

4.3.3 If it is known that the temperature of the cooling air exceeds the values given in *Pt 6, Ch 2, 1.5 Ambient temperatures*, the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling air.

4.4 Direct current service generators

4.4.1 Automatic voltage regulators are to be provided for shunt wound direct current generators.

4.4.2 Direct current generators used for charging batteries without series-regulating resistors are to be either:

(a) shunt-wound; or
(b) compound-wound with switches arranged so that the series winding can be switched out of service.

4.4.3 Means are to be provided at the switchboard to enable the voltage of generators required to run in parallel to be adjusted separately.

4.4.4 For each direct current generator, coupled to its prime mover, at any temperature within the working range, the means required by *Pt 6, Ch 2, 4.4 Direct current service generators 4.4.3* is to be capable of adjusting the voltage at any load between no load and full load to within:

(a) 0,5 per cent of rated voltage for generators of rating exceeding 100 kW; and

(b) 1,0 per cent of rated voltage for generators of rating not exceeding 100 kW.

4.4.5 The inherent Regulation of ships' service generators is to be such that the following conditions are satisfied:

(a) For shunt or stabilized shunt-wound generators, when the voltage has been set at full load, the steady voltage at no load shall not exceed 115 per cent of the full load value, and the voltage obtained at any intermediate value of load shall not exceed the no load value.
(b) For compound-wound generators with the generator at full load operating temperature, and starting at 20 per cent load with voltage within one per cent of rated voltage, then at full load the voltage is to be within 2,5 per cent of rated voltage. The average of the ascending and descending load/voltage curves between 20 per cent load and full load is not to vary more than four per cent from rated voltage.

4.4.6 Generators are to be capable of delivering continuously the full load current and normal rated voltage at the terminals when running at full load engine speed at all ambient temperatures up to the specified maximum.

4.4.7 Generators required to run in parallel are to be stable from no load up to the total combined load of the group, and load sharing is to be satisfactory.

4.4.8 The series winding of each two-wire generator is to be connected to the negative terminal.

4.4.9 Equalizer connections are to have a cross-sectional area appropriate to the system but in no case less than 50 per cent of that of the negative connection from the generator to the switchboard.

4.5 Alternating current service generators

4.5.1 Each alternating current service generator, unless of the self-regulating type, is to be operated in conjunction with a separate automatic voltage regulator.

4.5.2 The voltage regulation of any alternating current generator with its AVR is to be such that at all loads from zero to full load the rated voltage at rated power factor is maintained under steady conditions within ±2,5 per cent.

4.5.3 Alternating current generators required to run in parallel are to be stable from 20 per cent full load (kW) up to the total combined full load (kW) of the group, and load sharing is to be satisfactory. The facilities for adjusting the governor of an alternating current generating set, at normal frequency, are to be sufficiently fine to permit an adjustment of load on the prime mover to within five per cent of full load.

4.5.4 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from their proportionate share of the total kVA load by more than five per cent of the rated kVA output of the largest machine when operating at 0,8 power factor.

4.6 Inspection and testing

4.6.1 On machines for essential services, tests are to be carried out in accordance with the relevant standard and a certificate furnished by the manufacturer.

4.6.2 Generators and motors of 100 kW or over intended for essential services are to be inspected by the Surveyors during manufacture and testing.

■ *Section 5*
Switchgear assemblies, switchgear and fusegear - Construction and testing

5.1 Switchgear assemblies

5.1.1 Switchboards, section boards and distribution boards are to be so installed that live parts are sufficiently guarded and adequate space is provided for maintenance, also they are to be protected where necessary in way of pipes and to be constructed from, or enclosed with, non-flammable non-hygroscopic material.

5.1.2 All measuring instruments and all apparatus controlling circuits are to be clearly and indelibly labelled for identification purposes. An indelible label is to be permanently secured to, or adjacent to, every fuse and every circuit-breaker, and marked with particulars of the full load current of the generator or cable which the fuse or circuit-breaker protects. Where inverse time limit and/or reverse current devices are provided in connection with a circuit-breaker, the appropriate settings of these devices are to be stated on the label. Nameplates are to be of flame-retardant material.

5.2 Instruments

5.2.1 Sufficient instrumentation is to be provided for measuring voltage, current, frequency and power for alternating current generators greater than 50 kW.

5.2.2 Where alternating current generators are required to operate in parallel, synchronizing arrangements are to be fitted.

5.3 Instrument transformers

5.3.1 The secondary windings of instrument transformers are to be earthed.

5.4 Switchgear

5.4.1 Circuit-breakers and switches are to be of the air break type and are to be constructed in accordance with an acceptable National or International Standard.

5.4.2 Reports of tests to establish the capacity of circuit-breakers, are to be submitted for consideration when required.

5.4.3 Overcurrent releases are to be calibrated in amperes, and settings marked on the circuit-breaker.

5.5 Fuses

5.5.1 Fuses are to comply with an acceptable National or International Standard.

5.5.2 Fuse-links and fuse-bases are to be marked with particulars of rated current and rated voltage. Each fuse position is to be permanently and indelibly labelled with the current-carrying capacity of the circuit protected by it and with the appropriate approved size of fuse or replaceable element.

5.6 Testing

5.6.1 Before installation, switchboards complete or in sections with all components, are to pass the following tests at the manufacturer's works and a certificate furnished. A high voltage test is to be carried out on all switching and control apparatus for systems greater than 60 V with a test voltage of 1000 V plus twice the rated voltage (minimum 2000 V) at any frequency between 25 and 100 Hz for one minute applied between:

(a) all current-carrying parts connected together and earth; and
(b) between current-carrying parts of opposite polarity or phase.

5.6.2 For systems of 60 V or less, the test shall be at 500 V for one minute.

5.6.3 Instruments and ancillary apparatus may be disconnected during the high voltage test.

5.6.4 Immediately after the high voltage test, the insulation resistance between:

(a) all current-carrying parts connected together and earth, and
(b) between current-carrying parts of opposite polarity or phase,

shall be not less than one MΩ when tested with a direct current voltage of at least 500 V.

■ *Section 6*
Controlgear - Construction and testing

6.1 General

6.1.1 Controlgear is to comply with an acceptable National or International Standard.

6.1.2 Controlgear, including isolating and reversing switches, is to be so arranged that shunt field circuits are not disconnected without an adequate discharge path being provided.

6.2 Testing

6.2.1 Controlgear and resistors are to be tested by the makers with a high voltage applied between the earthed frame and all live parts. The test voltage is to be 1000 V plus twice the rated voltage with a minimum of 2000 V. The voltage is to be alternating at any frequency between 25 and 100 Hz and is to be maintained for one minute without failure.

6.2.2 Instruments and auxiliary apparatus may be disconnected during the high voltage test.

6.2.3 Immediately after the high voltage test, the insulation resistance between:

(a) current-carrying parts connected together and earth; and
(b) between current-carrying parts of opposite polarity or phase;

shall be not less than one MΩ when tested with a direct current voltage of at least 500 V.

■ *Section 7* Cables - Construction and testing

7.1 General

7.1.1 Cables are to be in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in*Pt 6, Ch 2, 1.5 Ambient temperatures*.

7.2 Insulating materials

7.2.1 Permitted insulating materials with maximum rated conductor temperatures are given in *Table 2.2.1 Maximum operating conductor*.

7.2.2 Where a rubber or rubber-like material with maximum conductor temperature greater than 60°C is used, it is to be readily identifiable.

7.2.3 Other insulating materials will be considered.

7.3 Sheaths and protective coverings

7.3.1 Cables are to be protected by one or more of the following, and the sheath or protective covering is to be compatible with the insulation:

(a) Sheath

Lead-alloy sheath

Copper sheath

Non-metallic sheath

(b) Protective covering

Steel-wire armour

Steel-tape armour

Metal-braid armour

(basket weave)

Fibrous braid.

7.3.2 Unsheathed cables, e.g. rubber-insulated taped and braided or equivalent, may be used only if installed in conduit.

7.3.3 **Non-metallic sheath**. Polychloroprene compound, polyvinyl chloride compound and chlorosulphonated polyethylene may be used for impervious sheaths. Other compounds will be considered.

7.3.4 **Fibrous braid.** Textile braid is to be of cotton, hemp, glass or other equivalent fibre, and is to be of strength suitable for the size of the cable. It is to be effectively impregnated with a compound which is resistant to moisture, and flame retarding except where flame-extending cables are permitted by *Pt 6, Ch 2, 2.19 Choice of protective covering 2.19.2*.

7.3.5 Cable outer sheath of cables are to be resistant to oil and oil vapour.

7.4 Testing

7.4.1 Tests in accordance with an acceptable National or International Standard are to be made at the manufacturer's works prior to despatch.

■ *Section 8*
Transformers - Construction and testing

8.1 General

8.1.1 Transformers are to be in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in *Pt 6, Ch 2, 1.5 Ambient temperatures*.

8.2 Construction

8.2.1 Transformers, except those for motor starting, are to be double wound.

8.3 Regulation

8.3.1 The inherent regulation at 0,8 power factor is not to exceed five per cent.

8.3.2 Regulation of the complete system is to comply with *Pt 6, Ch 2, 2.20 Current rating 2.20.2*.

8.4 Short-circuit

8.4.1 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for two seconds.

8.5 Tests

8.5.1 Transformers for essential services are to be tested by the manufacturers in accordance with the relevant standard and test certificates supplied.

■ *Section 9*
Batteries - Construction and testing

9.1 Construction

9.1.1 The cells of all batteries are to be so constructed and secured as to prevent spilling of the electrolyte due to the motion of the ship, and to prevent emission of acid or alkaline spray.

9.1.2 For lithium battery system installations *see Pt 6, Ch 2, 12 Batteries* of the *Rules and Regulations for the Classification of Ships, July 2022*.

9.2 Supports

9.2.1 Batteries are to be so arranged that each cell or crate of cells is accessible from the top and at least one side.

9.2.2 Cells or crates are to be carried on non-absorbent insulating supports. Similar insulators are to be fitted to prevent any movement of cells arising from the motion of the ship.

■ Section 10
Accessories - Construction and testing

10.1 Enclosures

10.1.1 Enclosures are to be of metal or of flame-retardant insulating materials.

10.2 Inspection and draw boxes

10.2.1 If metal conduit systems are used, inspection and draw boxes are to be of metal and are to be in rigid electrical and mechanical connection with the conduits.

10.3 Socket outlets and plugs

10.3.1 Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

10.3.2 All socket outlets of current rating 16 A or more are to be provided with a switch.

■ Section 11
Heating and cooking equipment

11.1 Construction and testing

11.1.1 Heaters are to be so constructed, installed and protected that clothing, bedding and other flammable material cannot come in contact with them in such a manner as to cause risk of fire. There is to be no excessive heating of adjacent bulkheads or decks.

■ Section 12
Installation of equipment

12.1 Cables

12.1.1 Cable runs are to be, as far as possible, straight and accessible.

12.1.2 Cables having insulating materials with different maximum-rated conductor temperatures are not to be bunched together, or, where this is not practicable, the cables are to be operated so that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.

12.1.3 Cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

12.1.4 The minimum internal radius or bend of installed cables is to be generally in accordance with:

$4d$ for cables without braiding, armouring or other metal
sheath and with an overall diameter not exceeding 25 mm

$6d$ for all other cables

(d = overall diameter of cable).

12.2 Mechanical protection of cables

12.2.1 Cables exposed to risk of mechanical damage are to be protected by metal channels or casing or enclosed in steel conduit unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible damage.

12.2.2 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured, unless the steel structure affords adequate protection. *See also Pt 6, Ch 2, 13.6 Cables and cable installation*.

12.2.3 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

12.3 Earthing of metal coverings

12.3.1 Metal coverings of cables are to be effectively earthed at both ends of the cable, except in final sub-circuits where earthing at the supply end only will be considered adequate. This does not necessarily apply to instrumentation cables where single point earthing may be desirable for technical reasons.

12.3.2 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

12.3.3 The lead sheath of lead-sheathed cables is not to be used as the sole means of earthing the non-current carrying parts of items of equipment.

12.4 Securing of cables

12.4.1 Cables are to be effectively supported and secured without their coverings being damaged.

12.4.2 The distances between supports is to be chosen according to the type of cable.

12.4.3 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection.

12.5 Penetration of bulkheads and decks by cables

12.5.1 Penetration of watertight bulkheads or decks is to be carried out with either individual watertight glands or with packed watertight boxes carrying several cables. However carried out, the watertight integrity of the bulkheads or decks is to be maintained.

12.5.2 Cables passing through decks are to be protected by deck tubes or ducts.

12.5.3 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with lead or other approved material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

12.5.4 Materials used for glands and bushings are to be such that there is no risk of corrosion.

12.5.5 Where rectangular holes are cut in bulkheads or structural steel, the corners are to be radiused.

12.6 Installation of cables in pipes and conduits

12.6.1 Metal conduit systems are to be earthed and are to be mechanically and electrically continuous across joints. Individual short lengths of conduit need not be earthed.

12.6.2 The internal radius of bend of pipes and conduit is to be not less than that laid down for cables, provided that for pipes exceeding 64 mm diameter, the internal radius of bend is not less than twice the diameter of the pipe.

12.6.3 The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-section area of the pipe) is not to exceed 0,4.

12.6.4 Expansion joints are to be provided where necessary.

12.6.5 Where necessary, ventilation openings are to be provided at the highest and lowest points to permit air circulation and to prevent accumulation of water.

12.6.6 Where cables are laid in trunks, the trunks are to be so constructed as not to afford passage for fire from one ‘tween deck or compartment to another.

12.6.7 Non-metallic ducting or conduit is to be of flame retardant material. PVC conduit is not to be used in refrigerated spaces or on open decks, unless specially approved.

12.7 Cables for alternating current

12.7.1 Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20 A, the requirements of *Pt 6, Ch 2, 12.7 Cables for alternating current 12.7.2* are to be complied with.

12.7.2 Cables are to be either non-armoured or armoured with non-magnetic material.

12.7.3 If installed in pipe or conduit, cables belonging to the same circuit are to be installed in the same conduit, unless the conduit or pipe is of non-magnetic material.

12.7.4 Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

12.7.5 In the installation of two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits or three-phase and neutral circuits, the cables are to be in contact with one another, as far as possible. In any event the distance between adjacent cables is not to be greater than one diameter.

12.7.6 If single-core cables of current rating greater than 250 A are run along a steel bulkhead. Wherever practicable, the cables should be spaced away from the steel.

12.7.7 Where single-core cables of rating exceeding 50 A are used, magnetic material is not to be placed between single-core cables of a group. If these cables pass through steel plates, all cables of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables, and suitable clearance is provided between the cable core and magnetic material. This clearance, wherever practicable, is to be not less than 75 mm when the current exceeds 300 A. For currents between 50 A and 300 A, the clearance is to be obtained by interpolation.

12.8 Cable ends

12.8.1 The ends of all conductors or cross-sectional area greater than 4 mm^2 are to be fitted with soldering sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

12.8.2 Cables having a hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

12.8.3 Cables with a supplementary insulating belt beneath the protective sheath are to have additional insulation at those points where the insulation of each core makes or may make contact with earthed metal.

12.9 Joints and branch circuits in cable systems

12.9.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. Terminals or busbars are to be of dimensions adequate for the cable rating.

12.10 Batteries

12.10.1 Alkaline batteries and lead acid batteries are not to be installed in the same compartment.

12.10.2 Large batteries are to be installed in a space assigned to the batteries only or alternatively in a deck box if such a space is not available.

12.10.3 Engine starting batteries are to be located as close as practicable to the engine(s) served. If such batteries cannot be accommodated in the battery room, they are to be installed so that adequate ventilation is ensured.

12.10.4 Where acid is used as the electrolyte, a tray of lead, or wood lined with lead, is to be provided below the cells. Alternatively, the deck below the cells is to be protected with lead or other acid-resisting material which effectually prevents any acid from lodging in contact with the ship's structure.

12.10.5 The interiors of all battery compartments, including shelves, are to be painted with corrosion-resistant paint.

12.10.6 Switches, fuses and other electrical equipment liable to cause an arc are not to be fitted in battery compartments.

12.10.7 Batteries are to be so arranged that each cell or crate of cells is accessible from the top and at least one side.

12.10.8 Cells or crates are to be carried on non-absorbent insulating supports. Similar insulators are to be fitted to prevent any movement of cells arising from the motion of the ship.

12.10.9 Battery compartments are to be ventilated by an independent ventilating system.

12.10.10 Natural ventilation may be employed if ducts can be run directly from the top of the compartment to the open air with no part of the duct more than 45° from the vertical. If natural ventilation is impracticable, mechanical ventilation is to be provided. Interior surfaces of ducts and fans are to be protected against corrosion. Fan motors are not to be located in the air stream.

12.10.11 All openings through the battery compartment bulkheads or decks, other than ventilation openings, are to be effectively sealed to reduce the possibility of escape of gas from the battery compartment into the ship.

12.10.12 Where practicable, battery lockers are to be ventilated in the same manner as battery compartments.

12.10.13 Deck boxes are to be adequately ventilated and means provided to prevent ingress of water.

12.10.14 A permanent notice is to be fitted to all battery compartments prohibiting naked lights and smoking.

12.11 Lighting

12.11.1 Lighting of cargo spaces is to be controlled by multi-pole linked switches situated outside these spaces. Provision is to be made for the complete isolation of these circuits and locking in the OFF position of the means of control.

12.12 Socket outlets and plugs

12.12.1 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

12.12.2 In all wet situations, socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

■ *Section 13*
Special requirements for tankers intended for the carriage in bulk of oil and other hazardous liquids

13.1 General

13.1.1 In addition to the requirements of other relevant Sections, the special requirements of this Section apply to:

(a) *Pt 6, Ch 2, 14 Additional requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point of 60°C and below (closed cup test)* – Tankers for the carriage in bulk of oil cargoes having a flash point of 55°C and below (closed cup test).

(b) *Pt 6, Ch 2, 15 Additional requirements for tankers intended for the carriage in bulk of other hazardous liquids*– Tankers for the carriage in bulk of other hazardous liquids.

13.2 Earthing and bonding for the control of static electricity

13.2.1 Bonding straps are required for cargo tanks, process plant and piping systems which are not permanently connected to the hull of the ship either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1 MΩ.

13.2.2 Where bonding straps are required, they are to be of copper or other approved material, are to be protected against damage and, where necessary, electrolytic action.

13.2.3 Bonding straps are to be installed where they are clearly visible and in an accessible position to allow ease of installation and replacement.

13.3 Systems of supply

13.3.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire insulated,

(b) a.c., single-phase, two-wire insulated,

(c) a.c., three-phase, three-wire insulated,

(d) a.c., three-phase, four-wire with neutral solidly earthed but without hull return.

13.4 Distribution

13.4.1 No current carrying part of an insulated distribution system is to be earthed, other than through an earth indicating device or through components used for the suppression of radio interference.

13.5 Fuses

13.5.1 Rewireable type fuses are not to be fitted.

13.6 Cables and cable installation

13.6.1 Electric cables are not to be installed in dangerous zones or spaces, except as permitted in certain paragraphs of this Section or *Pt 6, Ch 2, 14 Additional requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point of 60°C and below (closed cup test)*, or when associated with intrinsically safe circuits.

13.6.2 All cables which may be exposed to cargo oil, oil vapour or gas are to be sheathed with at least one of the following:

(a) Copper sheath (for mineral insulated cable).
(b) Lead alloy sheath plus further mechanical protection, e.g. armour or non-metallic impervious sheath.
(c) Non-metallic impervious sheath plus armour (for mechanical protection and earth detection).

13.6.3 Where corrosion may be expected, non-metallic impervious sheath is to be applied over steel armour.

13.6.4 Cables installed on deck are to be protected against mechanical damage. Cables are to be installed so as to avoid strain or chafing, and due allowance is to be made for expansion or working of the structure. Where expansion bends are fitted, they are to be accessible for maintenance.

13.6.5 Where cables pass through gastight bulkheads or decks, separating dangerous zones or spaces from non-dangerous zones or spaces, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

13.6.6 Cables installed in pump-rooms are to be suitably protected against mechanical damage.

13.6.7 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g. neither led on the same casing or pipe nor secured by the same fixing clip.

13.7 Transmitting aerials

13.7.1 Transmitting aerials should be sited well clear of the cargo zone as defined in *Pt 6, Ch 2, 13.9 Dangerous zones or spaces*.

13.8 Certified safe type equipment

13.8.1 Where reference is made to the following ‘safe’ types of equipment:

(a) Intrinsically safe (symbol i).
(b) Flameproof (symbol d).
(c) Increased safety (symbol e).
(d) Pressurized enclosure (symbol p).

Such equipment is to be certified for the gases and vapours involved. The construction and type testing is to be in accordance with IEC Publication 60079, *Electrical Apparatus for Explosive Gas Atmospheres*, or an equivalent National Standard. Where it is considered necessary to use certified ‘safe’ type equipment with protection types non-incendive (symbol n), encapsulated (symbol m), powder filled (symbol p) or special protection (symbol s) details are to be submitted for consideration by LR.

13.8.2 In addition, lighting fittings of the air driven type with a pressurized enclosure are considered to be a ‘safe’ type of lighting fitting.

13.8.3 When safe type equipment is permitted in dangerous zones or spaces, all switches and protective devices are to interrupt all lines or phases and are to be located in a non-dangerous zone or space unless specifically permitted otherwise. Such equipment, switches and protective devices are to be suitably labelled for identification purposes.

13.9 Dangerous zones or spaces

13.9.1 Dangerous zones or spaces are indicated in *Pt 6, Ch 2, 14 Additional requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point of 60°C and below (closed cup test)*, but the following general principals are to apply:

(a) Spaces containing flammable cargo and all zones or spaces adjacent to cargo tanks are regarded as dangerous zones or spaces.
(b) An enclosed or semi-enclosed space with direct access into a dangerous zone or space is regarded as a dangerous space.
(c) An enclosed space located in a dangerous zone or space may be regarded as a non-dangerous space, provided that it is separated from the flammable liquid cargo by not less than two gastight steel bulkheads or decks, is mechanically ventilated and in addition, has no direct opening into a dangerous zone or space.

13.9.2 Where the ship is designed to allow visits to terminals where the whole ship is regarded as a dangerous zone or space, or the dangerous zones or spaces are otherwise extended, due to the loading terminal height in relation to the associated ship height, this capability is to be identified in the plans required by *Pt 6, Ch 2, 1.2 Plans 1.2.2*, including the associated extended dangerous zones or spaces. Electrical equipment and other components that can create sparks that are intended to be used in the extended hazardous areas during loading and discharging are to be of a safe-type or, alternatively, are to have a non-ventilated enclosure of ingress protection rating of at least IP55, or equivalent acceptable to LR.

13.9.3 Where *Pt 6, Ch 2, 13.9 Dangerous zones or spaces 13.9.2*is applicable, other electrical equipment, and other components that can create sparks, that do not satisfy the constructional requirements of *Pt 6, Ch 2, 13.9 Dangerous zones or spaces 13.9.2*and are located in the extended dangerous zones or spaces are to be marked red and are to be automatically isolated and shutdown during loading and discharging, *see also Pt 6, Ch 2, 13.13 Spaces maintained at overpressure*and *Pt 6, Ch 2, 13.14 Automatic isolation overrides*.

Note: Compliance with the requirements and operating practices of the relevant statutory authorities during visits to such terminals is the responsibility of the Owner.

13.10 Semi-enclosed spaces

13.10.1 Semi-enclosed spaces are considered to be spaces limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation are sensibly different from those obtained on open deck.

13.11 Connections between entrained ships

13.11.1 A suitable earthing connection is to be provided between metalwork of the hulls to ensure equal potential of all entrained ships. These connections, preferably bolted, may be incorporated in the mechanical coupling arrangements, *see Pt 6, Ch 2, 2.23 Connections between entrained ships*.

13.12 Electrical apparatus

13.12.1 Where the cargo is liable to damage materials normally used in the construction of electrical apparatus, special consideration is to be given to the materials selected for conductors, insulation and metal parts and/or the protection thereof.

13.13 Spaces maintained at overpressure

13.13.1 Where spaces are maintained at an overpressure to prevent the space being considered a hazardous zone or space, the requirements of this sub-Section are to be complied with.

13.13.2 Arrangements are to be provided to maintain spaces at an overpressure of at least 0,1 kPa relative to external hazardous areas by ventilation from a non dangerous area.

13.13.3 Air intakes are to be located at least 2 m from hazardous zones and at least 2 m above the deck. Hazardous zones are considered to be:

- The tank deck and spaces up to 3 m above or away from the deck (the tank deck is considered to start from the deck above the cofferdam bulkhead not adjacent to the tank and to extend upwards at an angle of 45° towards the tank to the height of 3 m); and
- zones within a 2 m radius around any pipe, flanged joint or tank opening or glands or other openings through which leakage of cargo oil or other hazardous liquids may occur under normal operating conditions.

In the case of gas or vapour having a relative density of more than 0,75, the hazardous zone is considered to extend vertically downwards.

13.13.4 Electrical equipment, and other components that can create sparks, required to operate upon loss of overpressure or gas detection in spaces maintained at overpressure are to be of a safe-type or, alternatively, are to have a non-ventilated enclosure of ingress protection rating of at least IP55, or equivalent acceptable to LR.

13.13.5 The space pressure is to be monitored continuously and on loss of pressurisation:

- equipment in those spaces that does not satisfy the constructional requirements of *Pt 6, Ch 2, 13.13 Spaces maintained at overpressure 13.13.4* is to be automatically isolated; and
- alarms are to be provided in the accommodation to indicate the loss of space pressure.

The arrangements are to prevent automatically isolated equipment being energized until the atmosphere within the space is made safe.

13.13.6 A permanently installed system of gas detection equipment is to be provided in spaces maintained at overpressure and is to satisfy the requirements of *Pt 6, Ch 2, 13.13 Spaces maintained at overpressure 13.13.7*.

13.13.7 The positions of gas detector heads are to be determined with due regard to the dilution resulting from compartment purging or ventilation and to areas where pockets of gas may accumulate. Due regard is to be given to locating gas detector head at entrances or windows, at ventilation intakes and in appropriate lower positions in spaces where it is intended to carry cargoes with associated gas that is heavier than air.

13.13.8 Gas detection systems are to be suitable for measuring gas resulting from leakage from the intended cargoes of concentrations of 0 to 100 per cent by volume.

13.13.9 Gas detection equipment is to be capable of continuous monitoring. Alternative proposals for sequential detector sampling and analysing may be submitted for consideration where it can be demonstrated that an acceptable level of safety is achieved in all applicable spaces.

13.13.10 When a gas concentration of 20 per cent of the lower explosive limit (LEL) of the gas resulting from leakage from the intended cargoes is detected:

- equipment that does not satisfy the constructional requirements of *Pt 6, Ch 2, 13.13 Spaces maintained at overpressure 13.13.4* is to be automatically isolated in the relevant space(s), *see also Pt 6, Ch 2, 13.14 Automatic isolation overrides*; and
- alarms are to be provided in the accommodation, wheelhouse, and spaces maintained at overpressure to indicate detection of gas in the relevant space(s).

The arrangements are to prevent automatically isolated electrical equipment being energized until the atmosphere within the space is made safe.

13.13.11 Gas detection equipment is to be so designed that it may be readily tested. Testing and calibration is to be capable of being carried out at regular intervals. Equipment in fan casings is to allow calibration to take into account airflow.

13.13.12 Gas detection systems are to be ‘fail-safe’, *see also Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.6*.

13.14 Automatic isolation overrides

13.14.1 Where it would prevent the non-availability of essential services for the propulsion and safety of the ship, arrangements are to be provided on the bridge to allow the overriding of the automatic isolation and shutdown measures required by *Pt 6, Ch 2, 13.9 Dangerous zones or spaces 13.9.3* and *Pt 6, Ch 2, 13.13 Spaces maintained at overpressure 13.13.10* that can be operated during normal voyage mode, *see also Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.9*.

■ *Section 14*
Additional requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point of 60°C and below (closed cup test)

14.1 Electrical equipment permitted in dangerous zones or spaces

14.1.1 Sub-Sections *Pt 6, Ch 2, 14.2 Below deck cargo zones* define the electrical equipment permitted in dangerous zones or spaces.

14.2 Below deck cargo zones

14.2.1 **Cargo tank.** Intrinsically safe electrical equipment.

14.2.2 Cofferdams adjoining cargo tanks:

(a) Intrinsically safe electrical equipment.
(b) Electric depth-sounding devices hermetically enclosed located clear of the cargo tank bulkhead, with cables installed in heavy gauge steel pipe with gastight joints up to the main deck.
(c) Where it is necessary for cables to pass through spaces, other than those supplying the equipment described in this paragraph, they are to be installed in heavy gauge steel pipes with gastight joints.

14.2.3 Cargo pump-rooms:

(a) Electrical equipment as defined in *Pt 6, Ch 2, 14.2 Below deck cargo zones 14.2.2*.

(b) **Lighting.** Pump-rooms immediately adjoining an engine room or similar non-dangerous space may be lit through permanently fitted glass lenses or ports fitted in the bulkhead on deck, so arranged as to maintain integrity of the structure. The externally mounted lighting fixture may be designed so that the gastight flanged port forms part of the fixture. The lighting fixtures and wiring are to be located in the non-dangerous space.

(c) Alternatively, flameproof lighting fittings (symbol d) may be fitted. The fittings are to be arranged on at least two independent final branch circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

(d) Lighting fittings of the air driven type, *see Pt 6, Ch 2, 13.8 Certified safe type equipment 13.8.2*.

(e) **Motors**. Electrical motors driving equipment located in cargo pump-rooms are to be separated from the pump-room by a gastight bulkhead or deck. Flexible couplings or other means of maintaining alignment are to be fitted in the shafts between the motors and the driven unit. In addition, suitable stuffing boxes are to be fitted where shafts pass through gastight bulkheads or decks.

(f) **Cables.** Where it is necessary for cables other than those supplying lighting to pass through cargo pump-rooms, they are to be installed in heavy gauge steel pipes with gastight joints.

14.2.4 Spaces other than cofferdams adjoining and below the top of a cargo tank e.g. holds:

(a) Intrinsically safe equipment.

(b) Safe type lighting fittings, *see Pt 6, Ch 2, 13.8 Certified safe type equipment*.

(c) Through runs of cable.

(d) Special consideration is to be given to the mechanical protection of electrical equipment in such spaces.

14.3 Above deck cargo zone

14.3.1 Safe type equipment, *see Pt 6, Ch 2, 13.8 Certified safe type equipment*. Such equipment is to be suitably protected for use on deck.

14.3.2 Through runs of cable.

14.4 Adjoining parts of above deck cargo zone

14.4.1 Safe type equipment, *see Pt 6, Ch 2, 13.8 Certified safe type equipment*. Such equipment is to be suitably protected for use on deck.

14.4.2 Through runs of cable.

14.5 Enclosed or semi-enclosed spaces having bulkheads in line with cargo tank bulkheads

14.5.1 Safe type equipment, *see Pt 6, Ch 2, 13.8 Certified safe type equipment*. Such equipment is to be suitably protected for use on deck where necessary.

14.5.2 Through runs of cable.

14.6 Compartments for cargo hoses

14.6.1 Intrinsically safe equipment.

14.6.2 Safe type lighting fittings, *see Pt 6, Ch 2, 13.8 Certified safe type equipment*.

14.6.3 Through runs of cable.

14.7 Cargo tank level, pressure and temperature measurement

14.7.1 Independent 1st stage and 2nd stage high level alarms are to be provided for cargo tanks. The 2nd stage high level alarm is to be set at a maximum tank level of 97.5%. Level indication is also to be provided locally to each tank.

14.7.2 'Fail-safe' arrangements (*see Pt 6, Ch 1, 2.4 Safety systems – General requirements 2.4.6*) are to be provided to shutdown loading and discharging pumps and compressors to operate in the event of activation of either high cargo tank level alarm required by *Pt 6, Ch 2, 14.7 Cargo tank level, pressure and temperature measurement 14.7.1*.

14.7.3 The high cargo tank level alarms required by *Pt 6, Ch 2, 14.7 Cargo tank level, pressure and temperature measurement 14.7.1* are to be both audible and visual and are to be provided on the wheelhouse and on the tank deck.

14.7.4 Indication of cargo tank pressure and temperature on an analogue display is to be provided in the wheelhouse and at the tank deck for all fluids and gasses where dangerous situations may arise, for example venting resulting from environmental effects causing heating of tanks.

14.7.5 To determine where the dangerous situations referred to in *Pt 6, Ch 2, 14.7 Cargo tank level, pressure and temperature measurement 14.7.4*may arise, reference is to be made to the A.D.N. and the relevant requirements of the appropriate National, International or Local Authorities. The applicability of *Pt 6, Ch 2, 14.7 Cargo tank level, pressure and temperature measurement 14.7.4* is to be identified in the in the plans required by *Pt 6, Ch 2, 1.2 Plans 1.2.2*.

14.8 Loading and discharging pump control

14.8.1 Cargo pumps are to be provided with means to stop the pumps in an emergency in the wheelhouse and at appropriate locations for the pump on the tank deck.

14.9 Inert gas monitoring

14.9.1 Systems providing inert gas to cargo spaces are to be provided with a loss of pressurization and an overpressure alarm (minimum setting 3,5 kPa underpressure and 7 kPa overpressure, *see also Pt 5, Ch 13, 9 Inert gas systems*) for the relevant cargo spaces. The alarms are to be both audible and visual and are to be provided on the wheelhouse.

14.10 Cargo control rooms

14.10.1 Where a cargo control room is provided for the monitoring and control of cargo operations, the arrangements are to comply with *Pt 6, Ch 2, 14.10 Cargo control rooms 14.10.2*.

14.10.2 The applicable alarms and indications required by *Pt 6, Ch 2, 13 Special requirements for tankers intended for the carriage in bulk of oil and other hazardous liquids*(including those for cargo tank level, temperature and pressure) are, additionally, to be provided in the cargo control room.

14.10.3 Where means to control cargo valves remotely are provided, these are to permit control from the cargo control room.

14.10.4 Cargo pump room ventilation outlets are to be situated at least 6 m from accommodation entrances.

14.11 Cargo pump room gas detection

14.11.1 Pump rooms below the upper deck are to be provided with a system of gas detection that satisfies the requirements of *Pt 6, Ch 2, 13.13 Spaces maintained at overpressure 13.13.4*, as applicable.

14.11.2 The gas detection system is to automatically isolate electrical equipment that does not satisfy the constructional requirements of *Pt 6, Ch 2, 13.13 Spaces maintained at overpressure 13.13.4* and provide audible and visual alarms in the pump room and in the wheelhouse to indicate detection of gas when a gas concentration of 10 per cent of the *lower explosive limit* (LEL) of the gas resulting from leakage from the intended cargoes is detected. The arrangements are to prevent automatically isolated electrical equipment being energized until the atmosphere within the space is made safe.

14.11.3 Gas detection heads are to be located at the entrances to the cargo pump rooms and in appropriate lower positions in the space.

14.12 Cargo tank heating

14.12.1 Where thermal oil or hot water cargo tank heating arrangements are provided that includes equipment located outside of dangerous zones and spaces, arrangements are to be provided to activate an audible and visual alarm in the event of loss of heating system overpressure required to prevent cargo fluids entering heating system piping as a result of leaks in the heating system coils or other components located in the tank. Alarms are to be activated at an appropriate pressure taking into account, as necessary, the heating system operating pressures and design cargo static head.

14.13 Tank deck sprinkler systems

14.13.1 Sprinkler systems installed on tank deck are to be provided with means of control in the wheelhouse and locally.

■ Section 15
Additional requirements for tankers intended for the carriage in bulk of other hazardous liquids

15.1 General

15.1.1 For cargoes possessing flammable characteristics similar to those of oil products, the requirements are to be based on the closed cup test flash point and vapour pressure at ambient temperature.

15.1.2 For cargoes having a flash point of 60°C and below (closed cup test), *Pt 6, Ch 2, 14.1 Electrical equipment permitted in dangerous zones or spaces* are to be complied with where applicable. This requirement is based on the assumption that there are no additional hazards due to chemical reaction.

15.1.3 For cargoes which, due to chemical instability or chemical reaction may generate flammable gases or vapours, the electrical installation is to be in accordance with *Pt 6, Ch 2, 15.1 General 15.1.2*.

15.1.4 Where the cargo is liable to damage materials normally used in the construction of electrical apparatus, special consideration is to be given to the materials selected for conductors, insulation and metal parts and/or the protection thereof.

■ Section 16
Special requirements for lightning conductors

16.1 General

16.1.1 Lightning conductors are to be fitted to each mast of all wood, composite, and steel ships having wooden masts or topmasts. They need not be fitted to steel ships having steel masts. Where lightning conductors are fitted they are to comply with*Pt 6, Ch 2, 14 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

■ Section 17
Additional requirements for passenger ships

17.1 General

17.1.1 Passenger ships are to comply with the applicable additional requirements of this Section.

17.2 Main fire zones and damage stability

17.2.1 Where the ship contains main fire zones, emergency services and their emergency power supplies that are required to be capable of being operated under fire conditions or in the event of damage are to be so arranged that a fire in a main fire zone does not affect the operation of the emergency services in any other main fire zone.

17.2.2 Where the ship contains flooding zones for damage stability, electrical equipment (for example cables and connections, switchboards, section and distribution boards and protective devices) required to provide essential services required for the propulsion and safety of the ship and for emergency services are to be located above the damage stability level as far as is practicable.

17.3 Lighting

17.3.1 Lighting is to be provided by suitable electrical equipment only.

17.3.2 For the following spaces and locations, both main and emergency lighting is to be provided:

(a) at all stowage and designated preparation positions for life-saving appliances;

(b) at all muster stations and, where applicable, embarkation stations and oversides;
(c) escape route alleyways, stairways and exits;
(d) accommodation areas, cabins and personnel lift cars;
(e) in other areas intended for use by persons with reduced mobility;
(f) in the machinery spaces and main generating stations, including their control positions and their exits;
(g) in the wheelhouse;
(h) at all stowage positions for fireman's outfits;

See also Pt 6, Ch 2, 2.7 Lighting circuits 2.7.4.

17.3.3 Where required, additional emergency lighting indicating escape routes and emergency exits (e.g. low location lighting) is to be provided with an emergency power supply and is to be in accordance with the relevant requirements of the appropriate National, International or Local Authorities.

17.4 Emergency services

17.4.1 The following emergency services, where required by National, International or Local Authorities, are to be provided with emergency power supplies capable of supplying the services for 30 minutes:

- emergency lighting;
- signal lights;
- searchlights;
- fire and general alarms;
- public address systems;
- passenger and crew warning systems;
- fire detection and alarm systems;
- fire-extinguishing systems and fire-extinguishing media release alarms;
- automatic sprinkler systems;
- control and power systems to power-operated watertight doors and fire doors and their status indication;
- personnel lifts and lifting equipment for persons with reduce mobility provided for evacuation purposes;
- emergency bilge pump and equipment necessary for the operation of remote controlled bilge valves; and
- davits and hoisting gear for gangways intended for emergency use and rescue boats, where installed.

17.4.2 Emergency arrangements to bring the lift cars to deck level for the escape of persons are to be provided supplied from an emergency power supply. The passenger lift cars may be brought to deck level sequentially in an emergency.

17.5 Passenger and crew warning system

17.5.1 An internal alarm system is to be provided that permits persons on board to alert responsible ship personnel and is to be in accordance with *Pt 6, Ch 2, 17.5 Passenger and crew warning system 17.5.2*.

17.5.2 The system is to be provided with means of activation at the following places:

- in each cabin;
- in corridors, lifts and stairwells with the distance to the nearest trigger not exceeding 10 m and with at least one trigger for each watertight compartment;
- in lounges, dining rooms and similar recreation rooms;
- in toilets, intended for use by persons with reduced mobility;
- in engine rooms, galleys and similar rooms where there is a fire risk; and
- in the cold-storage rooms and other store rooms with deck surface area greater than 4 m^2.

Additional means of activation may be provided at other locations considered appropriate.

17.5.3 The means of alarm activation are to be protected against unintentional use and are to be installed at a height above the deck of 0,85 m to 1,10 m.

17.5.4 Upon activation, an alarm is to be given in designated areas for the responsible ship personnel.

17.5.5 The system is to be arranged to allow alarms to be reset, accepted or otherwise handled only by responsible ship personnel.

17.6 General emergency alarm system

17.6.1 Required electrically operated bell or klaxon or other equivalent warning systems for sounding the general emergency alarm signal are to comply with the relevant requirements of the appropriate National, International or Local Authorities and with the requirements of this sub- Section.

17.6.2 The system is to be capable of sounding a clearly distinguishable general emergency alarm in:

(a) all rooms accessible to passengers; and
(b) all spaces occupied by shipboard personnel (including crew recreation rooms, cold-storage rooms and other store rooms).

17.6.3 Means are to be provided to allow the system to be capable of sounding the alarm required by *Pt 6, Ch 2, 17.6 General emergency alarm system 17.6.2.(b)* independently of the alarm to the passenger spaces required by *Pt 6, Ch 2, 17.6 General emergency alarm system 17.6.2*.

17.6.4 Means are to be provided to permit the alarm to be activated from the wheelhouse and from a location that is permanently attended by ship personnel.

17.6.5 The means of alarm activation are to be protected against unintentional use.

17.7 Public address system

17.7.1 Required public address systems are to comply with the relevant requirements of the appropriate National, International or Local Authorities and with the requirements of this sub-Section.

17.7.2 The public address system is to be capable of broadcasting messages from the wheelhouse to:

- all passenger areas;
- control stations where there is no other direct communication means from the wheelhouse; and
- in the access and evacuation areas for passengers.

Loudspeakers may be omitted in passenger areas where it can be demonstrated that effective direct communication between the wheelhouse and the passenger area is possible due to proximity and the lack of barriers.

17.7.3 The system is to be designed in such a way as to ensure that the information transmitted can be clearly distinguished from background noise.

17.8 Watertight doors

17.8.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit. Watertight doors are to be capable of being supplied with main and emergency electrical power.

17.8.2 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

17.8.3 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm in the wheelhouse.

17.8.4 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

17.8.5 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water with ratings as defined in *IEC 60529: Degrees of protection provided by enclosures (IP Code)* or an acceptable and relevant National Standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 standard.
(b) Door position indicators and associated circuit components protected to IPX8 standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 standard.

17.8.6 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the ship may sustain is minimized.

17.8.7 An audible alarm, distinct from any other alarm in the area, is to sound automatically whenever the door is closed by power. When a door is closed remotely, the audible alarm is to sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

17.8.8 Power operated watertight doors are to be provided with an additional hand-operated mechanism capable of operating independently of the power operation. It is to be possible to open and close the door by hand at the door itself from either side. Direction of rotation or other movement is to be clearly indicated at door operating positions.

17.8.9 Power operated watertight doors are to be capable of being closed in not more than 60 s with the ship in the upright position. The closing time of watertight doors is not to be less than 30 s. The time necessary for the complete closure of the door, when operating by hand gear, is to not exceed 90 s with the ship in the upright position.

17.8.10 Indicators are to be provided at watertight door remote control positions to indicate when a door is fully closed or open.

17.8.11 The arrangements are to be such that it is not possible to remotely open any watertight door.

■ *Section 18* **Trials**

18.1 General

18.1.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the trials in *Pt 6, Ch 2, 18.2 Insulation resistance* are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

18.2 Insulation resistance

18.2.1 Insulation resistance is to be measured using a self-contained instrument such as a direct reading ohm-meter of the generator type applying a voltage of at least 500 V. Where a circuit incorporates capacitors of more than 2 μF total capacitance, a constant-voltage type instrument is to be used to ensure accurate test readings.

18.2.2 **Power and lighting circuits.** The insulation resistance between all insulated poles and earth and where practicable, between poles, is to be at least 1 MΩ. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than this figure.

18.2.3 **Low voltage circuits.** Circuits operating at less than 50 V are to have an insulation resistance of at least 0,33 MΩ.

18.2.4 **Switchboards, section boards and distribution boards.** The insulation resistance is to be at least 1 MΩ when measured between each busbar and earth and between busbars. This test may be made with all circuit-breakers and switches open, all fuse links for pilot lamps, earth fault-indicating lamps, voltmeters, etc. removed and voltage coils temporarily disconnected, where otherwise damage may result.

18.2.5 **Generators and motors.** The insulation resistance of generators and motors, in normal working condition and with all parts in place, is to be measured and recorded. The test should be carried out with the machine hot, if possible. The insulation resistance of generator and motor cables, field windings and controlgear is to be at least 1 MΩ.

18.3 Earth continuity

18.3.1 Tests are to be made to verify that all earth continuity conductors and bonding straps are effective and that the bonding and earthing of metallic conduit and/or sheathing of cables is effective.

18.4 Performance

18.4.1 It is to be demonstrated that the Rules have been complied with in respect of *Pt 6, Ch 2, 18.4 Performance 18.4.2*.

18.4.2 Satisfactory commutation and performance of each generator throughout a run at full rated load.

18.4.3 Temperatures of joints, connections, circuit-breakers and fuses.

18.4.4 The operation of engine governors, synchronizing devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices.

18.4.5 Voltage regulation of every generator when full rated load is suddenly thrown off.

18.4.6 For alternating current and direct current generators, satisfactory parallel operation and kW load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load. For alternating current generators, satisfactory parallel operation and kVA load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load.

18.4.7 All essential motors and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

18.5 Voltage drop

18.5.1 Voltage drop is to be measured, where necessary, to verify that this is not excessive, *see Pt 6, Ch 2, 2.20 Current rating*.

Section 1
General

1.1 General

1.1.1 It is the responsibility of the Government of the flag state to give effect to the fire safety measures applicable to the particular ship type. However, Lloyd's Register (hereinafter referred to as 'LR') will undertake to do this in cases where:

(a) Contracting Governments have authorised LR to apply the requirements specified by that Government and issue the appropriate certification on their behalf; or

(b) the Government of the Flag State has no relevant National requirements.

1.1.2 When implementing the provisions of *Pt 6, Ch 3, 1.1 General 1.1.1.(b)*, LR will apply as appropriate either:

- the fire safety measures required by European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN); or
- the fire safety measures required by European Agreement concerning the international carriage of dangerous goods by Inland Waterways (ADN).

However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the intended service of the vessel.

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